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THE

MINERALOGICAL MAGAZINE

AND

Journal of The Mineralogical Society.

INSTITUTED FEBRUARY 3, 1876.

EDITED BY L. J. SPENCER, M.A.

ASSISTED BY A COMMITTEE OF COUNCIL.

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1911.

MINERALOGICAL SOCIETY.

(*Instituted February* 3, 1876.)

BYE-LAWS.

1. The object of the Mineralogical Society of Great Britain and Ireland, with which the Crystallological Society was amalgamated on December 11, 1883, shall be to advance the knowledge of Mineralogy, and also of Crystallography and Petrology.

2. The Society shall consist of Ordinary Members and Honorary Members.

Ordinary Members.

3. Every candidate for Ordinary Membership shall be proposed by two Ordinary Members, one, at least, of whom shall have personal knowledge of the candidate.

4. Elections to Ordinary Membership shall be made by the Council, and shall be confirmed at the ensuing general meeting by a majority consisting of three-fourths of the Members present and voting.

5. Ordinary Members shall pay an entrance fee of one guinea and an annual subscription of one guinea. Ordinary Members elected on or before November 13, 1900, shall be entitled to compound for the annual subscription by a single payment of ten guineas: Ordinary Members elected after that date shall be entitled to compound for the annual subscription by a single payment of fifteen guineas.

6. Annual Subscriptions shall be due on the first of January of each year, but Members elected after the first of October shall not be required to pay a subscription for the then current year.

7. The name of any Ordinary Member whose subscription is more than two years in arrear shall be brought before the Council, and an intimation that this action has been taken shall be communicated to the Member. After the expiration of at least one year from that date, the Council shall be empowered to erase the name from the List of Members.

Honorary Members.

8. Twenty persons, non-resident in the United Kingdom, may be elected Honorary Members. They shall pay neither entrance fee nor annual subscription.

9. Every candidate for Honorary Membership shall be proposed by two Members of the Council, and the election shall be by the Council, and shall be confirmed at the ensuing general meeting by a majority consisting of three-fourths of the Members present and voting.

Council.

10. The Society shall be governed by a Council, consisting of a President, two Vice-Presidents, a General Secretary, a Foreign Secretary, a Treasurer, an Editor of the Journal, and twelve Ordinary Members.

11. All members of the Society who have served the office of President shall be life-members of the Council.

12. The Council shall be elected annually at the Anniversary Meeting.

13. Four Ordinary Members of Council shall retire annually, and shall not be eligible for re-election until the next Anniversary Meeting.

14. The Council shall prepare a List of Members nominated for election as Officers and Ordinary Members of Council.

15. The election of Council shall be effected by the agency of voting papers containing the List nominated by the Council. They shall be sent by the General Secretary, at least four weeks before the Anniversary Meeting, to every Ordinary Member of the Society, and every such Member shall be entitled to substitute the names of any other Ordinary Members of the Society for those on the List.

16. The voting papers shall be returned by the Members to the General Secretary, and shall be examined at the Anniversary Meeting by two Scrutineers appointed by the Chairman, who shall on their report declare the result of the election. The voting papers need not be signed.

17. The Council shall have power to appoint Officers, and to co-opt Ordinary Members of Council to fill vacancies in the Council caused by death or resignation during the interval between two Anniversary Meetings.

18. Meetings of the Council shall be summoned by order of the President or the Council; at such meetings three shall be a quorum, of whom

one shall be either the President, a Vice-President, the Treasurer, or the General Secretary.

19. A Report of Council on the work and progress of the Society shall be submitted to each Anniversary Meeting.

Trustees.

20. Two or more Trustees shall be appointed by the Council, and the invested property of the Society shall stand in their names.

21. Composition-fees shall be treated as Capital: a Resolution of the Society at a general meeting, summoned with notice of a proposed disposition of property, shall be sufficient authority to the Trustees to give effect to such disposition; provided that a resolution of the Council shall be sufficient authority for any change of investment.

Meetings.

22. Meetings of the Society shall be summoned from time to time, as may be deemed necessary by the Council, or at the requisition of any ten Members of the Society. One of these meetings in each year shall be termed the Anniversary Meeting.

Journal.

23. The Numbers of the *Mineralogical Magazine and Journal of the Society* shall be issued at such intervals as the Council shall determine, and shall be sent, postage paid, to every Member of the Society.

Auditors and Balance Sheet.

24. Two Ordinary Members of the Society, one of whom is not a Member of the Council, shall be appointed annually by the Council to audit the accounts of the Society.

25. No auditor shall serve for more than three years in succession.

26. The audited Balance Sheet, after submission to the Council, shall be published in the Journal of the Society as early as possible in every year.

Expulsion of Members.

27. A majority consisting of three-fourths of the whole Council shall have power to expel a Member from the Society, but a Member who has been expelled shall have a right of appeal to the Society. Notice of such appeal to the Society shall be sent by such Member to the

General Secretary within four weeks of the expulsion, and the appeal shall be considered by the Society at the next Anniversary Meeting; a majority of the votes recorded at such Meeting sufficing to confirm or annul the decision of the Council.

Alteration of the Bye-Laws.

28. The Bye-laws may be altered only at an Anniversary Meeting, and only by a majority consisting of three-fourths of the Members present and voting. Notice of changes proposed to be made in the Bye-laws shall be communicated by the General Secretary to every Ordinary Member of the Society at least four weeks before the Anniversary Meeting at which they are to be considered.

Obligation Book.

29. Ordinary Members, by payment of their entrance fee, signify their acceptance of any Bye-laws approved by the Society; and every Member of the Society shall sign an Obligation Book.

LIST OF MEMBERS.

(*March*, 1911.)

HONORARY MEMBERS.

Year of Election.

1905 Baumhauer, Heinrich. Professor of Mineralogy in the University of *Freiburg, Switzerland.*

1909 Becke, Friedrich Johann. Professor of Mineralogy and Petrography in the University of *Vienna.*

1895 Brögger, Waldemar Christofer. Professor of Mineralogy and Geology, and Rector of the University, *Christiania.*

1879 Brush, George Jarvis. Yale University, *New Haven, Conn., U.S.A.*

1909 Calderón y Arana, Salvador. Professor of Mineralogy and Botany in the University of *Madrid.*

1909 Cesàro, Giuseppe. Professor of Mineralogy in the University of *Liége.*

1897 Dana, Edward Salisbury. Yale University, *New Haven, Conn., U.S.A.*

1910 Fedorov, Evgraf Stepanovič. Professor of Mineralogy in the Institute of Mines (Gornyi Institut) of the Empress Catherine II, *Vasili Ostrov, St. Petersburg.*

1877 Groth, Paul Heinrich von. Professor of Mineralogy in the University of Munich. *Brieffach, München VI.*

1900 Lacroix, Alfred. Professor of Mineralogy in the Muséum d'Histoire Naturelle. 61 *Rue de Buffon, Paris.*

C[1] Lang, Victor von. Professor of Physics in the University of Vienna. *Physikalisches Institut der Universität, Vienna.*

1898 Lévy, Auguste Michel. Professor in the Collège de France. 62 *Boulevard St. Michel, Paris.*

1903 Liebisch, Theodor. Professor of Mineralogy in the University of Berlin. *Mineralogisch-petrographisches Institut, Invalidenstrasse* 43, *Berlin No.* 4.

1883 Ludwig, Ernst. 9 *Allgemeines Krankenhaus, Vienna.*

[1] C = Corresponding Member of the Crystallological Society at the time of the amalgamation of the two societies, December 11, 1883.

Year of Election.

1879 Rosenbusch, Harry. Professor of Mineralogy and Geology in the University of *Heidelberg.*

1877 Steenstrup, Knud Johannes Vogelius. *Forchhammersvej* 15[1], *Copenhagen.*

1903 Strüver, Giovanni. Professor of Mineralogy in the Royal University of *Rome.*

1879 Tschermak, Gustav. The University, *Vienna.*

1879 Zirkel, Ferdinand. Formerly Professor of Mineralogy and Geognosy in the University of Leipzig. *Königstrasse* 2*a*, *Bonn-am-Rhein.*

ORDINARY MEMBERS.[1]

A. Annual Subscribers.
L. Life-Members.
C. Belonged to the Crystallological Society at the time of the amalgamation of the two Societies, December 11, 1883.

Year of Election.

L 1888 Arnold-Bemrose, Henry Howe, J.P., M.A., Sc.D., F.G.S. *Ash Tree House, Osmaston Road, Derby.*

A 1881 Baker, Harry, F.I.C., F.C.S. *Epworth House, Maughland Lane, Runcorn, Cheshire.*

A 1904 Barker, Thomas Vipond, M.A., B.Sc. (Oxon.), F.C.S. *Department of Mineralogy, University Museum, Oxford.*

L 1894 Barlow, William, F.R.S. *The Red House, Stanmore, Middlesex.*

L 1876 Barnett, Andrew Ketchan, F.G.S. 11 *Penrose Terrace, Penzance, Cornwall.*

L 1893 Barrow, George, F.G.S. Geological Survey of England, *The Museum*, 28 *Jermyn Street, London, S.W.*

L 1897 Beale, William Phipson, K.C., M.P., F.G.S., F.C.S. 10 *New Court, Carey Street, London, W.C.*

A 1894 Beringer, John Jacob, A.R.S.M., F.I.C., F.C.S. *School of Metalliferous Mining, Camborne, Cornwall.*

A 1906 Blake, George Stanfield, B.Sc., A.R.S.M., F.C.S. *Shoal Point, Port-au-Port, Newfoundland.*

[1] Corrections for this List should be sent to the General Secretary.

	Year of Election.	
L	1876	Bonney, Rev. Thomas George, Sc.D., LL.D., F.R.S. Emeritus Professor of Geology in University College, London. 9 *Scroope Terrace, Cambridge.*
A	1909	Bowen, David, F.G.S. *The University, Leeds.*
L	1897	Bowman, Herbert Lister, M.A., D.Sc., F.G.S., F.C.S. Professor of Mineralogy in the University of Oxford. *Department of Mineralogy, University Museum, Oxford.*
L	1876	Brown, Alexander Crum, M.A., M.D., D.Sc., F.R.S. Formerly Professor of Chemistry in the University of Edinburgh. 8 *Belgrave Terrace, Edinburgh.*
A	1901	Burls, Herbert Thomas, F.G.S. 16 *Victoria Street, London, S.W.*
L	1885	Butler, Francis Henry, M.A., A.R.S.M., L.S.A. (Lond.), 158 *Brompton Road, London, S.W.*
A	1903	Campbell, Donald Fraser, B.A., A.R.S.M., F.G.S. *Old Hunstanton, Norfolk.*
A	1876	Church, Sir Arthur Herbert, K.C.V.O., M.A., D.Sc., F.R.S. Professor of Chemistry in the Royal Academy of Arts. *Shelsley, Ennerdale Road, Kew, Surrey.*
A	1888	Cole, Grenville A. J., M.R.I.A., F.G.S. Director of the Geological Survey of Ireland, Professor of Geology in the *Royal College of Science for Ireland, Dublin.*
L	1892	Collins, Henry F., A.R.S.M. *Huelva Copper and Sulphur Mines, Ltd., Val de la Musa, Prov. de Huelva, Spain.*
L	1876	Collins, Joseph Henry, F.G.S. *Crinnis, Par Station, Cornwall.*
L	1900	Coomaraswamy, Ananda K., D.Sc., F.L.S., F.G.S., M.R.A.S. *Norman Chapel, Broad Campden, Gloucestershire.*
A	1907	Crook, Thomas, A.R.C.Sc.I., F.G.S. *Scientific and Technical Department, Imperial Institute, London, S.W.*
L	1888	Crookes, Sir William, O.M., D.Sc., LL.D., F.R.S. 7 *Kensington Park Gardens, London, W.*
A	1899	Cullis, Charles Gilbert, D.Sc., F.G.S. Assistant-Professor of Geology in the *Imperial College of Science and Technology, South Kensington, London, S.W.*
L	1899	Currie, James, M.A., F.R.S.E. *Larkfield, Golden Acre, Edinburgh.*
L	1876	Danby, Thomas William, M.A., F.G.S. *The Crouch, Seaford, Sussex.*

	Year of Election.	
L	1885	Daw, John W. *Walreddon Manor, Tavistock, Devon.*
L	1898	De Castro, John Paul, M.A., F.C.S., F.I.C. 1 *Essex Court, Temple, London, E.C.*
A	1909	Dewey, Henry, F.G.S. Geological Survey of England. *The Museum,* 28 *Jermyn Street, London, S.W.*
L	1910	Drugman, Julien L. E., Ph.D. (Bonn), M.Sc., F.C.S. 23 *Iffley Road, Oxford.*
L	1891	Evans, John William, LL.B., D.Sc., F.G.S. Imperial Institute, London, S.W. 75 *Craven Park Road, Willesden Junction, London, N.W.*
L	1900	Fleischmann, Friedrich Noel Ashcroft, M.A., F.C.S., F.G.S. 37 *Palace Court, Bayswater, London, W.*
L	C	Fletcher, Lazarus, M.A., Hon. Ph.D. (Berlin), F.R.S. Director of the British Museum (Natural History), Cromwell Road, London, S.W. 35 *Woodville Gardens, Ealing, London, W.*
L	1895	Fletcher, Rev. Mark, M.A., F.G.S. Demonstrator in Mineralogy in the Armstrong College, Newcastle-on-Tyne. *The Vicarage, North Sunderland, Chathill S.O., Northumberland.*
L	1902	Flett, John Smith, M.A., D.Sc., F.R.S.E., F.G.S. Assistant Director, Geological Survey of Scotland. 33 *George Square, Edinburgh.*
A	1876	Geikie, Sir Archibald, K.C.B., D.Sc., D.C.L., LL.D., President R.S. Formerly Director-General of the Geological Survey of the United Kingdom. *Shepherd's Down, Haslemere, Surrey.*
A	1876	Geikie, James, LL.D., D.C.L., F.R.S. Professor of Geology and Mineralogy in the University of Edinburgh. *Kilmorie, Colinton Road, Edinburgh.*
L	1881	Gibb, T. J. 8 *Bush Lane, Cannon Street, London, E.C.*
L	1902	Giles, William B., F.I.C. *The Grange, Leyton, Essex.*
L	1886	Goldschmidt, Dr. Victor, Professor of Mineralogy in the University of Heidelberg. 9 *Gaisbergstrasse, Heidelberg, Germany.*
A	1905	Goodchild, Wilbert, M.B., Ch.B. (Edin.). *Blencathra Sanatorium, Threlkeld, Penrith, Cumberland.*
A	1895	Gordon, Rev. John More, M.A., F.G.S. *St. John's Vicarage, Redhill, Surrey.*
A	1903	Grabham, George Walter, M.A., F.G.S. Geologist to the Sudan Government. *Box* 178, *Khartoum, Sudan.*

	Year of Election.	
L	1892	Gregory, John Walter, D.Sc., F.R.S. Professor of Geology in the *University of Glasgow.*
A	1900	Hall, Arthur Lewis, B.A., F.G.S. *Geological Survey Office, Box* 435, *Pretoria, Transvaal.*
A	1911	Hall, Thomas Clifford Fitzwilliam, F.G.S. *School of Metalliferous Mining, Camborne, Cornwall.*
A	1908	Harger, Harold Scott, F.G.S. *P. O. Box* 1945, *Johannesburg, Transvaal.*
A	1885	Harker, Alfred, M.A., F.R.S. Fellow of St. John's College, Cambridge. *St. John's College, Cambridge.*
A	1898	Hartley, Ernald George Justinian, B.A., F.C.S. *The Bungalow, Boar's Hill, near Oxford.*
L	1900	Hartley, Harold Brewer, M.A., F.C.S. *Balliol College, Oxford.*
A	1910	Hatch, Frederick Henry, Ph.D., M.Inst.C.E., F.G.S. *Southacre, Trumpington Road, Cambridge.*
A	1910	Henson, Mrs. F. 97 *Regent Street, London, W.*
A	1879	Henson, Samuel, 97 *Regent Street, London, W.*
A	1910	Heslop, Miss Mary Kingdon, M.Sc. 25 *Eastbourne Terrace, London, W.*
L	1907	Hilton, Harold, M.A. 73 *Platts Lane, Hampstead, London, N.*
A	1888	Hoffmann, G. Christian, LL.D. *Care of A. F. May, Esq., Carleton Chambers,* 74 *Sparks Street, Ottawa, Canada.*
L	1896	Holland, Sir Thomas Henry, K.C.I.E., A.R.C.S., D.Sc., F.R.S. Formerly Director of the Geological Survey of India. Professor of Geology and Mineralogy in the Victoria University of Manchester. *The University, Manchester.*
A	1908	Hopkins, Edward. 58B *Hatton Garden, London, E.C.*
A	1902	Howe, John Allen, B.Sc., F.G.S. Curator of the Museum of Practical Geology. *The Museum,* 28 *Jermyn Street, London, S.W.*
A	1878	Hughes, Thomas McKenny, M.A., F.R.S. Professor of Geology in the University of Cambridge. *Ravensworth, Brooklands Avenue, Cambridge.*
A	1893	Hussak, Dr. Eugen. 49 *Rua Quitanda, Rio de Janeiro, Brazil, South America.*
L	1890	Hutchinson, Arthur, M.A., F.C.S., F.G.S. Demonstrator of Mineralogy in the University of Cambridge. *Pembroke College, Cambridge.*

	Year of Election.	
A	1899	JACKSON, Henry, M.A., B.Sc., F.C.S. *Downing College, Cambridge.*
A	1905	JONES, Bernard Mouat, B.A., F.C.S. Professor of Chemistry, *Government College, Lahore, India.*
A	1908	JONES, Owen Thomas, M.A., B.Sc., F.G.S. Professor of Geology in the University College of Wales. *University College, Aberystwith.*
L	1884	JUDD, John Wesley, C.B., LL.D., F.R.S. Formerly Professor of Geology in, and Dean of, the Royal College of Science, South Kensington, S.W. *Orford Lodge, 30 Cumberland Road, Kew, Surrey.*
L	1876	KINCH, Edward, F.C.S., F.I.C. Professor of Chemistry in the *Royal Agricultural College, Cirencester.*
L	1876	KITTO, Benedict, F.I.C., F.G.S. 26 *Lancaster Road, Finsbury Park, London, N.*
A	1909	KNOWLES, Thomas, B.A., B.Sc. *School of Metalliferous Mining, Camborne, Cornwall.*
A	1907	KRANTZ, Friedrich Ludwig Robert, Ph.D. 36 *Herwarth-Strasse, Bonn, Rhenish Prussia.*
A	1885	KUNZ, George Frederick, M.A., Ph.D., F.G.S. 401 *Fifth Avenue, New York City, U.S.A.*
A	C	LEWIS, William James, M.A., F.R.S., Professor of Mineralogy in the University of Cambridge. *The New Museums, Cambridge.*
A	1886	LINDSEY, C. R., B.Sc. 3 *Demesne Road, Whalley Range, Manchester.*
L	C	LIVEING, George Downing, M.A., Hon. Sc.D., F.R.S. Formerly Professor of Chemistry in the University of Cambridge. *Newnham, Cambridge.*
L	1876	LIVERSIDGE, Archibald, M.A., Hon. LL.D., F.R.S. Formerly Professor of Chemistry in the University of Sydney, New South Wales. *Hornton Cottage, Hornton Street, Kensington, London, W.*
A	1879	LOUIS, Henry, M.A., A.R.S.M., F.G.S. Professor of Mining in the *Armstrong College, Newcastle-on-Tyne.*
A	1910	MACALISTER, Donald Alexander, A.R.S.M., F.G.S. Geological Survey of England. *The Museum, 28 Jermyn Street, London, S.W.*
A	1902	MCGRIGOR, George Duncan, F.R.G.S. 25 *Charles Street, St. James's, London, S.W.*

Year of Election.

1908 McLintock, William Francis Porter, B.Sc. *The Museum, 28 Jermyn Street, London, S.W.*

1902 Maitland, Andrew Gibb, C.E., F.G.S. Government Geologist. *Geological Survey, Perth, Western Australia.*

1881 Mallet, Frederick Richard, F.G.S., F.C.S., F.I.C. 20 *King's Avenue, Ealing, London, W.*

1907 Mears, James Bartholomew, L.R.C.P., L.R.C.S. (Edin.). *Leuchars, Fifeshire, N.B.*

1902 Mennell, Frederic Philip, F.G.S. *P. O. Box* 140, *Bulawayo, Rhodesia.*

1876 Merry, J. S. *Swansea, South Wales.*

C Miers, Henry Alexander, M.A., D.Sc., F.R.S. Principal of the University of London. 23 *Wetherby Gardens, London, S.W.*

1876 Morris, James. 6 *Windsor Street, Swansea, South Wales.*

C Müller, Hugo, Ph.D., LL.D., F.R.S. 13 *Park Square East, Regent's Park, London, N.W.*

1880 Pearce, Richard, Ph.D., F.G.S. 43 *St. George's Court, Gloucester Road, London, S.W.*

1899 Pollard, William, M.A., D.Sc., F.G.S., F.C.S. Geological Survey of England. *The Museum*, 28 *Jermyn Street, London, S.W.*

1891 Pope, William Jackson, M.A., M.Sc., F.R.S. Professor of Chemistry in the University of Cambridge. *Holmesdale, Brooklands Avenue, Cambridge.*

1910 Porter, Miss Mary Winearls. 76 *Banbury Road, Oxford.*

1887 Prior, George Thurland, M.A., D.Sc., F.G.S. Keeper of Minerals in the *British Museum* (*Natural History*), *Cromwell Road, London, S.W.*

1908 Raisin, Miss Catherine Alice, D.Sc., F.L.S. *Bedford College, York Place, Baker Street, London, W.*

1903 Rastall, Robert Heron, M.A., F.G.S. *Christ's College, Cambridge.*

1876 Rudler, Frederick William, I.S.O., F.G.S. *Ethel Villa, Tatsfield, Westerham, Kent.*

1902 Russell, Arthur Edward Ian Montagu. *Swallowfield Park, Reading.*

1908 Schröder, Robert. 17 *Leopoldstrasse, Heidelberg, Germany.*

1876 Scott, Robert Henry, M.A., D.Sc., F.R.S. 6 *Elm Park Gardens, London, S.W.*

	Year of Election.	
A	1903	Scrivenor, John Brooke, M.A., F.G.S. Geologist to the Federated Malay States. *Kuala Lumpur, Federated Malay States.*
A	1884	Seligmann, Gustav. 6 *Neustadt, Coblenz, Rhenish Prussia.*
A	1908	Shand, S. James, B.Sc., Ph.D. *The Royal Scottish Museum, Edinburgh.*
L	1897	Smith, George Frederick Herbert, M.A., D.Sc., F.G.S., F.R.A.S. *British Museum (Natural History), Cromwell Road, London, S.W.*
A	1910	Smith, Walter Campbell, B.A., F.G.S. *British Museum (Natural History), Cromwell Road, London, S.W.*
A	1897	Sollas, William Johnson, M.A., D.Sc., LL.D., F.R.S. Professor of Geology in the University of Oxford. *The Museum, Oxford.*
A	C	Solly, Richard Harrison, M.A. *Hôtel Britannia, Cadenabbia, Lago di Como, Italy.*
A	1894	Spencer, Leonard James, M.A., F.G.S. *British Museum (Natural History), Cromwell Road, London, S.W.*
A	1878	Spezia, Giorgio. Professor of Mineralogy in the University, *Turin, Italy.*
A	C	Story-Maskelyne, Mervin Herbert Nevil, M.A., Hon. D.Sc., F.R.S. Late Professor of Mineralogy in the University of Oxford. *Basset Down House, Swindon, Wiltshire.*
A	1883	Teall, J. J. Harris, M.A., D.Sc., F.G.S. Director of the Geological Survey of Great Britain and of the Museum of Practical Geology. *The Museum,* 28 *Jermyn Street, London, S.W.*
A	1903	Thomas, Herbert Henry, M.A., B.Sc., F.G.S. Geological Survey of England. *The Museum,* 28 *Jermyn Street, London, S.W.*
L	1877	Trechmann, Charles Otto, J.P., Ph.D., F.G.S. *Hudworth Tower, Castle Eden, Co. Durham.*
A	1891	Tutton, Alfred Edwin Howard, M.A., D.Sc., F.R.S. 41 *Ladbroke Square, London, W.*
L	1894	Watts, William Whitehead, M.A., M.Sc., F.R.S. Professor of Geology in the *Imperial College of Science and Technology, South Kensington, S.W.*
L	1895	Webb, R. C.
L	1901	Weston, Digby St. A. P., Lieutenant R.N. 131 *Cromwell Road, London, S.W.*

Year of Election.

1876 Wills, Joseph Lainson, F.C.S. 133 *Midwood Street, Brooklyn, N.Y., U.S.A.*

1896 Wills, Louis.

1904 Woodgate, John, M.I.M.M. *Gattertop, Leominster, Herefordshire.*

C Woodward, Charles J., B.Sc., F.G.S. *The Lindens, St. Mary's Road, Harborne, Birmingham.*

1902 Young, Alfred Prentice, Ph.D., F.G.S. *Care of Messrs. Grindlay & Co.*, 55 *Parliament Street, London, S.W.*

SOCIETIES, INSTITUTIONS, ETC.

To which the Publications of the Mineralogical Society are sent.

(Those sending Publications in Exchange are marked with an asterisk.)

LONDON: Royal Society, *Burlington House, W.*
Geological Society „ „
Chemical Society „ „
British Museum (Natural History), *South Kensington, S.W.*
Museum of Practical Geology, 28 *Jermyn Street, S.W.*
Imperial Institute, *South Kensington, S.W.*

OXFORD: Department of Mineralogy, University Museum.

NEWCASTLE-ON-TYNE: North of England Institute of Mining Engineers.

TRURO: *Royal Institution of Cornwall.

HULL: Yorkshire Naturalists' Union. (*T. Sheppard, The Municipal Museums, Hull.*)

EDINBURGH: Royal Society.
*Geological Society, 5 *St. Andrew's Square.*

GLASGOW: University of Glasgow.
*Geological Society, 207 *Bath Street.*

DUBLIN: Royal Irish Academy, 19 *Dawson Street.*

PARIS: *Société française de Minéralogie, *Sorbonne.*

BRUSSELS: Société belge de Géologie, de Paléontologie et d'Hydrologie.

LIÉGE: *Société géologique de Belgique.

LEIPZIG: *Zeitschrift für Krystallographie und Mineralogie. (*Dr. Stefan Kreutz, Basztowa 3, Krakau, Galicia, Austria.*)

STUTTGART: Neues Jahrbuch für Mineralogie, &c. (*Schweizerbart'sche Verlagshandlung*).

BERLIN: Zeitschrift für praktische Geologie. (*Prof. Max Krahmann, Berlin NW. 23, Händelstrasse 6.*)

MUNICH: Technische Hochschule.

HALLE: K. Leopoldinisch-Carolinische Deutsche Akademie der Naturforscher.

VIENNA: *K.-K. Naturhistorisches Hofmuseum, *Burgring.*
K.-K. Geologische Reichsanstalt.
*Tschermak's Mineralogische und Petrographische Mitteilungen. (*Prof. F. Becke, Mineralogisches Institut der Universität.*)

UPSALA: *Kongl. Universitets-Biblioteket.
HELSINGFORS: Administration des Mines.
ST. PETERSBURG: Mineralogical Society.
ROME: *Ufficio Geologico, *Via Sta. Susanna.*
NAPLES: *Società Reale, Accademia delle Scienze Fisiche e Matematiche.
PISA: *Società Toscana di Scienze Naturali.
*Il Nuovo Cimento. (*A. Battelli.*)
PADOVA: *Rivista di Mineralogia e Cristallografia. (*Prof. R. Panebianco, The University.*)
BUCAREST: Institut Géologique de Roumanie.
SYDNEY: Royal Society of New South Wales.
*Australian Museum.
WELLINGTON: New Zealand Institute.
BULAWAYO: Rhodesia Scientific Association, *P. O. Box* 240.
NEW BRUNSWICK: Department of Mines, Nova Scotia.
WASHINGTON (D. C.): *United States Geological Survey.
Smithsonian Institution.
NEW YORK: *American Institute of Mining Engineers, 99 *John Street, New York City.*
NEW HAVEN (Conn.): *American Journal of Science.
PHILADELPHIA (Penn.): Academy of Sciences.
BALTIMORE (Maryland): Johns Hopkins University.
CHICAGO: University of Chicago (Journal of Geology).
LANCASTER (Penn.): Economic Geology, 41 *North Queen Street.*
BERKELEY (California): University of California.
MANILA (Philippine Islands): *Bureau of Government Laboratories.
BUENOS AYRES: *Sociedad Científica Argentina.

PROCEEDINGS

OF THE

MINERALOGICAL SOCIETY.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, Nov. 15, 1910, *at* 5 *p.m.*

Professor W. J. Lewis, M.A., F.R.S., Vice-President, in the Chair.

Dr. Julien Drugman, Miss Mary Kingdon Heslop, and Mrs. F. Henson were elected Ordinary Members of the Society.

The following were selected as the dates of meeting for the year 1911: Tuesdays, January 24, March 21, June 13, and November 14, the last to be the Anniversary Meeting.

The Annual Report of Council, submitted by the Secretary, was approved.

ANNIVERSARY MEETING.

Held in the Apartments of the Geological Society, Nov. 15, 1910, *at* 5.30 *p.m.*

Professor W. J. Lewis, M.A., F.R.S., Vice-President, in the Chair.

Thirty-four Members and two Visitors were present.

The elections of Dr. J. Drugman, Miss M. K. Heslop, and Mrs. F. Henson to the Ordinary Membership were confirmed.

The scrutineers reported that forty voting papers had been returned, and that the list as nominated by the Council was approved, namely:—

President. Prof. W. J. Lewis, M.A., F.R.S.

Vice-Presidents. Prof. H. L. Bowman, M.A., D.Sc., F.G.S.
A. E. H. Tutton, M.A., D.Sc., F.R.S.

Treasurer. W. Phipson Beale, K.C., M.P., F.G.S., F.C.S.

General Secretary. G. T. Prior, M.A., D.Sc., F.G.S.

Foreign Secretary. Prof. W. W. Watts, M.A., Sc.D., F.R.S.

Editor of the Journal. L. J. Spencer, M.A., F.G.S.

Ordinary Members of Council.

T. V. Barker, M.A., B.Sc., F.C.S.
G. Barrow, F.G.S.
J. H. Collins, F.G.S.
C. G. Cullis, D.Sc., F.G.S.
J. W. Evans, LL.B., D.Sc., F.G.S.
F. N. A. Fleischmann, M.A., F.C.S.
Rev. J. M. Gordon, M.A., F.G.S.
H. Hilton, M.A.
J. A. Howe, B.Sc., F.G.S.
A. Hutchinson, M.A., F.G.S.
R. Pearce, Ph.D., F.G.S.
H. H. Thomas, M.A., B.Sc., F.G.S.

The following ANNUAL REPORT OF COUNCIL was read:—

During the Session 1909–10 four meetings have been held (by kind permission) in the Apartments of the Geological Society, Burlington House, W., at which twenty papers were read. Two numbers of the Journal (No. 71 published in March, and No. 72 in September) have been issued. They contain nineteen papers, a (fifth) list of new mineral names, and eleven reviews of new books. The Society is indebted to Dr. Tutton for the loan of two blocks for text-figures illustrating papers by Mr. Grabham and Dr. Herbert Smith in No. 72; to Prof. Bowman for defraying the cost of one of the plates illustrating his and Mr. Clarke's paper in No. 72; and to Dr. Prior for defraying the cost of the plate illustrating his papers in No. 71.

The balance-sheet of the year ending December 31, 1909, shows that the financial position of the Society is satisfactory. The assets (exclusive of the Library and the stock of the Journal) amounted to £759 19*s.* 11*d.* and the liabilities to £13 18*s.* 10*d.* The value of the Stock invested in the names of the trustees of the Society was on that date £686 10*s.*, corresponding to £13 9*s.* 2*d.* for each Life Member.

During the Session 1909–10 the Society has lost by resignation one Ordinary Member, and by death one Honorary Member, M. Émile Berrand, who was a Corresponding Member of the Crystallological Society before its amalgamation with the Mineralogical Society in 1883. Four Honorary Members and five Ordinary Members have been elected. The total number of members on November 14, 1910, was 135; of whom nineteen are Honorary. Of the Ordinary Members, fifty-one have compounded for their annual subscription.

The Council has to congratulate the Society on its continued prosperity.

On the motion of Mr. Butler seconded by Mr. Russell, the Report was adopted.

A vote of thanks to the Council of the Geological Society for permission to meet in the Apartments of the Society was carried.

The dates of meeting for 1911 proposed by the Council were approved.

The following papers were then read:—

1. Further notes on Wood-tin: by Mr. J. H. Collins (p. 30).

2. On the alteration of the felspar of granite to china-clay: by Mr. F. M. Coon.

3. On Wiltshireite, a new mineral from the Binnenthal: by Prof. W. J. Lewis.

4. A new locality for Phenacite in Cornwall: by Mr. Arthur Russell (p. 55).

Specimens in illustration of these papers were exhibited, and lantern-slides were shown to illustrate the papers of Mr. Collins and Mr. Coon.

The portrait of Dr. Fletcher, which had been presented to him before the meeting by Members of the Society and other friends, in recognition of his invaluable services as President for three years and as Secretary for twenty-one years, was also on view.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, January 24, 1911, *at* 5 *p.m.*

Professor W. J. Lewis, M.A., F.R.S., President, in the Chair.

Mr. Thomas Clifford Fitzwilliam Hall was elected an Ordinary Member of the Society.

Dr. G. F. Herbert Smith and Mr. F. N. A. Fleischmann were elected Auditors of the accounts for the year ending December 31, 1910.

The Editor was authorized to publish in the first number of the new volume of the Journal a list of Institutions to which the Journal is sent.

GENERAL MEETING.

Held in the Apartments of the Geological Society, January 24, 1911, *at* 5.30 *p.m.*

Professor W. J. Lewis, M.A., F.R.S., President, in the Chair.

Thirty-three Members and two Visitors were present.

The election of Mr. T. C. Fitzwilliam Hall to the Ordinary Membership was confirmed.

The following papers were read:—

1. The natural history of Kaolinite: by Mr. F. H. Butler (p. 63).
2. On Schwartzembergite: by Dr. G. F. H. Smith and Dr. G. T. Prior.
3. An improved form of total refractometer: by Mr. A. Hutchinson.
4. A case of electrostatic separation: by Mr. T. Crook.

MINERALOGICAL SOCIETY.

ABSTRACT OF RECEIPTS AND PAYMENTS FROM JANUARY 1 TO DECEMBER 31, 1910.

Receipts.	£ s. d.	£ s. d.
Balance from 1909		52 6 0
Subscriptions—(1) current	56 12 0	
(2) arrears	13 12 0	
(3) advance	4 3 0	
		74 7 0
Entrance fees and Compositions		24 3 0
Sale of publications—		
By Publishers	19 3 0	
By G. Savigar	2 0 11	
		21 3 11
Dividends on Stock		20 8 1
Members for extra plates (Bowman)	2 12 0	
,, ,, ,, (Prior)	1 18 6	
		4 10 6
		£196 18 6

Payments.	£ s. d.	£ s. d.
Printing Magazine (No. 71)	20 18 2	
Authors' copies	4 14 3	
Illustrations	2 16 6	
		28 8 11
Printing Magazine (No. 72)	39 17 8	
Authors' copies	6 9 0	
Illustrations	8 17 0	
		55 3 8
Miscellaneous Printing		4 4 4
Editor's Honorarium (1909)		10 10 0
,, Special Honorarium for Cataloguing		10 10 0
G. Savigar for care of stock of Publications (1909)		1 1 0
Porter's Fee		1 0 0
Postage and Parcels—		
Printers (Magazine)	4 17 0	
,, (Authors' copies)	7 5	
G. Savigar (1909)	3 3	
Hon. Secretary (1909)	12 6	
Hon. Treasurer (1909)	7 7	
		6 7 9
Investments		51 18 1
Bank Charges		0 1 3
Balance at Bank (credit)	44 19 10	
,, in Office (debit)	17 6 4	
		27 13 6
		£196 18 6

Examined and compared with the vouchers, and found correct.
13 *February*, 1911.

(*Signed*) F. N. A. FLEISCHMANN
G. F. HERBERT SMITH } Auditors.

Liabilities.	£	s.	d.
Owing for Editor's Honorarium (1910)	10	10	0
„ G. Savigar for care of stock of Publications (1910)	1	1	0
„ Do. for postage (1910)		6	11
„ Hon. Secretary for postage (1910)		9	0
„ Hon. Treasurer „ „ (1910)		8	10
Excess of assets over liabilities	791	6	2
	£804	1	11

Assets.	£	s.	d.	£	s.	d.
Balance at Bank (credit)	44	19	10			
„ in Office (debit)	17	6	4			
				27	13	6
Consols (£901 9*s.* 4*d.*, valued at £79$\frac{3}{4}$)				721	6	0
Sale of Publications—						
Owing from Publishers	44	5	0			
„ G. Savigar	10	17	5			
				55	2	5
				£804	1	11

The number of Life Members on December 31 was fifty-three.

The stock of Publications and the value of the Library are not included in the above assets. (*Signed*) W. P. BEALE,
February 13, 1911. *Hon. Treasurer.*

THE MINERALOGICAL MAGAZINE

AND

JOURNAL OF

THE MINERALOGICAL SOCIETY.

No. 73. May, 1911. Vol. XVI.

Some observations on pleochroism and idiophany in mineral plates.

By T. Crook, A.R.C.Sc. (Dublin), F.G.S.

Scientific and Technical Department, Imperial Institute.

[Read January 25, 1910.]

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1. General remarks.

In this paper an attempt is made to state and explain, in a simple manner, the essential features of the phenomena which are seen when plates of pleochroic minerals are examined in ordinary light.

The pleochroic effects exhibited by minerals are usually studied in light of practically normal incidence. For the observation of facial

colours, transparent crystals, or, better still, specially orientated cube-shaped pieces of minerals, are examined in ordinary light. In general, by this mode of observation, only facial colours are seen when ordinary light is used, and for the observation of axial colours[1] the incident light must be polarized.

It is otherwise if the plate be examined in light of oblique incidence; since in this case the transmitted portion of the light may be effectively polarized by the plate itself as a result of reflection and refraction. In consequence of this, under certain conditions, axial colours may predominate when the plate is examined in ordinary light; and interference effects may in some cases also be seen.

A thorough treatment of this subject of the pleochroism of plates in ordinary light, on a practical basis, would necessitate the examination of a large number of choice specimens of coloured minerals, carefully cut in various ways. On account of the scarcity and expensive nature of such specimens, the writer has not been able to get much variety of material for study; and in presenting the few observations on the subject which are contained in this paper, he does so without any pretence at exhaustive treatment. His chief aim is to show that, by considering the behaviour of plates in ordinary parallel rays of oblique incidence, and by correlating this with the behaviour of plates in a convergent beam, the latter is more easily understood. Moreover, by treating the subject as a whole in this way, the phenomena of pleochroism in ordinary light assume a form far more varied and interesting than that in which they are usually presented; and their observation in some cases is a matter of extreme simplicity.

In what follows it is assumed that the observer will take care to see that the light used is not appreciably polarized or analysed by any agency other than that of the surface of the plate itself and cleavage surfaces parallel to it.

2. Factors to be considered.

The explanation of the phenomena displayed by pleochroic plates in ordinary light involves the consideration of several factors, which may with advantage be stated at the outset. Of these factors, the following may be regarded as of chief importance, and perhaps sufficient to explain the effects observed.

[1] In this paper, the phrase 'axial colour' is used in the wide sense as meaning a single-ray colour in a doubly-refracting crystal.

(1) *Variation of absorption with change of direction.* In anisotropic minerals the absorption is generally different for different vibration-directions. Hence the colour of these minerals, when examined in ordinary white light, generally varies with the direction of transmission of the rays. For some directions this variation is so slight that no appreciable pleochroism results from a change of direction of the ray over a considerable angular distance. For other directions it is so pronounced that a slight variation in the direction of transmission may cause a striking change of colour.

A good example of a direction of transmission in the near vicinity of which the change is very sudden and striking, is an optic axis of a pleochroic biaxial crystal, the least deviation from which, except in the optic axial plane, is accompanied by an effective change in colour.

It is otherwise with the optic axis of a uniaxial crystal, which, unlike that of a biaxial crystal, is usually an axis of optical symmetry.[1] The vibration-changes accompanying deviations in the near vicinity of such an axis are of the same order as those which accompany change of direction in the axial planes of a biaxial crystal, and are characterized as a rule by a slow and gradual rather than a sudden change of colour.

(2) *Absorption-polarization*, usually produced when light traverses a pleochroic crystal along a direction of double refraction. The colour seen along such a direction in ordinary light is called a facial colour; and a plate yielding such a colour generally acts to some extent like a polarizer, its efficiency in this respect depending upon the difference between the amounts of absorption represented by the two axial colours of which the facial colour is composed. The emergent light corresponding to a facial colour may thus be regarded as partially plane-polarized, the plane of polarization coinciding with that of the least-absorbed ray. This phenomenon of partial polarization is exhibited in some degree by all pleochroic minerals, and is so frequently met with in pleochroic plates that it may be conveniently referred to in a general way as polarization by absorption.

Tourmaline is a familiar and extreme example of this; but tourmaline itself is very variable, and several other strongly pleochroic minerals are for some purposes quite as effective: e.g., penninite, biotite, and andalusite.

The longer the path of the ray in a pleochroic plate, the more pronounced is the absorption-polarization. In the extreme case illustrated

[1] The behaviour of amethystine quartz (p. 12) appears to indicate that, as regards absorption, this is not necessarily the case for all uniaxial crystals.

by dark tourmaline, the limiting thickness beyond which the facial colour becomes identical with the least-absorption axial colour, in consequence of the complete absorption of the ordinary ray, is quite small. But in many other minerals this limit is approximated to in fairly thin plates.

These considerations bring out a fact connected with absorption-polarization which is especially worthy of note; viz., that facial colours which are compounded of the extreme axial values in a strongly pleochroic plate approximate closely to the least-absorption axial value. This fact is of considerable importance in the explanation of absorption-figures, as we shall see later.

(3) *Reflection-polarization* which takes place in consequence of the fact that, for obliquely incident rays, the vibration-components parallel to the plate are partly lost by reflection, and the vibrations of the transmitted rays contain an excess of the components lying in the plane of incidence. We may therefore regard the transmitted refracted ray as partially plane-polarized, with its plane of polarization at right angles to the plane of incidence. This effect is inoperative for rays of normal incidence, and reaches its maximum for rays incident at the polarizing angle.

Experiment to illustrate the operation of absorption- and reflection-polarization in the same plate.

The operation of factors (2) and (3) can be shown conveniently by brown phlogopite, cleavage plates of which usually show a well-marked biaxial character, and exhibit the characteristic reddish-brown and greenish-grey axial colours. If a basal section of calcite two or three millimetres thick be placed between two such plates of phlogopite, and held close to the eye, a good uniaxial figure is observed, the crossed nicols effect being observed when the like axes are at right angles, and the parallel nicols effect when they are parallel. Now let the arrangement be such that, when the crossed nicols effect is obtained, the vibration-direction of least absorption lying in the plate adjacent to the observer is placed vertically, whilst that in the plate remote from the observer is placed horizontally; and let the latter plate be turned about this horizontal directioninto an oblique position. It will be found that, when a certain angle has been passed, the crossed nicols effect gives place to that for parallel nicols.[1]

[1] The best way to do this experiment is to cement the calcite section to one of the plates of phlogopite, as this facilitates manipulation.

The first part of the experiment is equivalent to the use of a tourmaline pincette arrangement for observing a figure in convergent polarized light, and illustrates absorption-polarization, which, as already mentioned, generally accompanies a facial colour. The second part of the experiment, which cannot be performed with similar results in the case of tourmaline, for reasons which will appear later, is clearly understood as a consequence of polarization by reflection and refraction. We may explain the whole experiment briefly as follows: When the plate of phlogopite is held with its face at right angles to the line of sight, the transmitted light is partially polarized, the plane of polarization coinciding with that of the less-absorbed ray. If, therefore, we place the vibration-direction of maximum absorption (b axis) at right angles to the plane of incidence, the plane of polarization of the transmitted light remains unchanged when the plate is tilted into an oblique position, since the vibration-directions of the refraction-polarized rays lie in the plane of incidence and all the directions lying in this plane are directions of weak absorption. If, on the other hand, the axis of maximum absorption be placed vertically, i. e. in the plane of incidence, the reflection-polarization effect militates against the absorption-polarization effect when the plate is tilted, the former predominating when a certain angle has been passed, and the plane of polarization consequently moves through 90°.

Either of the plates can be tilted, and if the experiment be repeated with the axes of the mica plates in different relative positions, it will be observed that the figure only changes when the axis of maximum absorption in the tilted plate is lying in the plane of incidence.

3. Classification of pleochroic plates.

The behaviour of pleochroic plates in ordinary light depends essentially upon the nature and disposition of the absorption axes in relation to the face of the plate. Thus, all the vibration-directions lying in the plate may have the same absorption value; or this value may vary with the vibration-direction between two extreme values. In either case the absorption for vibration-directions at right angles to the plate may be stronger or weaker than for those lying in the plate. For our present purpose, we may conveniently restrict our attention chiefly to plates containing the chief absorption axes, and classify them simply as follows:—

Case I.—Plates in which there is no variation of absorption for rays

whose vibration-directions are parallel to the face of the plate; e. g. basal sections of uniaxial minerals.[1]

(*a*) Ordinary ray more absorbed than extraordinary.

(*b*) Extraordinary ray more absorbed than ordinary.

Case II.—Plates in which, for rays whose vibration-directions are parallel to the face of the plate, the absorption varies with the direction of vibration; e.g. principal sections of uniaxial minerals, and axial sections of biaxial minerals.

(*a*) Absorption comparatively weak for vibration-directions at right angles to the plate.

(*b*) Absorption comparatively strong for vibration-directions at right angles to the plate.

The adoption of these sub-divisions will facilitate the treatment of a few examples illustrating the operation of the above-mentioned factors. Special attention will be given to biotite and phlogopite, cleavage plates of which are readily obtained and afford good material for study. In what follows we shall, for the sake of brevity, refer to the sub-divisions as Cases I (*a*), I (*b*), II (*a*), and II (*b*).

4. Behaviour of pleochroic plates in parallel rays.

Case I (*a*).—The readiest examples of this case are black 'uniaxial' biotite and green penninite, which are easily obtained in good cleavage plates. In these there is practically only one absorption value for rays whose vibration-directions are parallel to the cleavage. When such a plate is held at right angles to the line of sight, we see the axial colour due to the absorption of the ordinary ray. When the biotite is tilted into an oblique position, one usually sees little or no change, unless the plate contains numerous cleavage rifts. Basal plates of tourmaline act much in the same way. This is contrary to expectation. The absorption of the extraordinary ray in sections normal to the base is so comparatively small in biotite and tourmaline that one might expect a considerable diminution of absorption on tilting a basal plate. In penninite, the expected change takes place, the green axial colour for the ordinary ray giving place to a yellowish-green facial colour.

The optic axis in black biotite and tourmaline is a line of transmission in the vicinity of which there is no perceptible change of absorption with

[1] Many biaxial minerals, e. g. amazon-stone and black biotite, are practically 'dichroic' and are capable of yielding plates which act pleochroically much like basal plates of uniaxial minerals.

change of direction. In the above observation it should be noted that the length of path increases with the angle of incidence, and that the ordinary ray is to some extent impoverished by reflection-polarization; though these factors in this case appear to be relatively unimportant.

The pseudo-pleochroism of certain micas.—An interesting case of pseudo-pleochroism may be considered here, viz., that provided by a variety of so-called silver-mica which owes its silvery sheen to the presence of numerous cleavage rifts which overlap each other and reflect the light copiously.[1] If such a plate of mica of suitable thickness, say 0·5 mm. or so, be held with its face at right angles to the line of sight, it will be found to be opaque or only feebly translucent. On tilting the plate into an oblique position it becomes more transparent, the degree of transparency gradually reaching a maximum and then diminishing as the plate approaches the horizontal position. The fact that these plates show a greater degree of transparency when held obliquely, in spite of the apparently greater thickness which the light has to traverse, is not due to pleochroism. It is, indeed, best seen in the colourless silvery phlogopites which show practically no pleochroism; and moreover, we have just seen that in the case of black biotite, which is intensely pleochroic, the expected increase of transparency on tilting does not occur.

The phenomenon[2] is due to the action of the cleavage rifts, which overlap extensively and act as do the air-films in a 'pile of plates'. Ordinary light rays of normal incidence are more copiously reflected by a pile of clear transparent plates than are obliquely incident rays. This seems paradoxical when we consider the fact that for a single plate the oblique rays suffer more reflection than do those of normal incidence. The explanation of this property of a pile of plates becomes clear when we examine the pile in polarized light. We then find that when the plane

[1] 'Silver-mica' appears to be generally phlogopite. There are two sorts; one of which owes its sheen to the presence of rod-like inclusions lying along the lines of the pressure- and percussion-figures, the other to the presence of cleavage rifts. The former possesses in a pronounced degree the property of asterism; the latter, with which we are here dealing, shows pseudo-pleochroism. Cleavage rifts and rod-like inclusions may both be present in considerable quantities, but pseudo-pleochroism is not seen when the latter are abundant.

[2] It can be readily reproduced by taking a plate of transparent muscovite and splitting it into a number of plates. When these are superposed, the pile will be found to be practically opaque to normally incident rays if the plates are numerous enough, though it is comparatively transparent to obliquely incident rays.

of polarization coincides with the plane of incidence, the amount of light reflected gradually increases with the angle of incidence, at least up to a certain point. On the other hand, when the plane of polarization is at right angles to the plane of incidence, the amount of light reflected gradually diminishes as the angle increases.[1] Hence ordinary light of normal incidence is more copiously reflected than obliquely incident light, on account of the fact that the latter yields refraction-polarized rays which suffer comparatively little reflection.

The same holds good of the pseudo-pleochroic variety of silvery mica to which we have referred above ; it provides a natural and very efficient pile of plates, and transmits with comparative readiness the refraction-polarized ingredient of an obliquely incident ray, whereas it is relatively opaque to rays of normal incidence. Doubtless, however, absorption plays some part in making the silvery mica so effectively opaque to normally incident rays ; though the evidence available shows clearly that the phenomenon is essentially one of pseudo-pleochroism, arising from the presence of cleavage rifts.

Case I (*b*).—In this case, when the plate is tilted into an oblique position, the increased length of path and the loss of light by reflection-polarization both tend to emphasize the effect arising from increased absorption due to change in direction of the rays. Hence we should expect the change in this case to be more perceptible as a rule than in Case I (*a*).

It so happens, however, that examples of this case are rare among minerals. Magnesium platinocyanide, an artificial substance, the crystals of which are tetragonal, is a frequently quoted example, and should apparently be included here. It provides a good example of rapid change of absorption with change of direction in the near vicinity of the optic axis.

Green microcline (amazon-stone) furnishes an approximation to this case, and since it yields fairly good cleavage plates which can be readily obtained, it is worthy of note as a specially interesting instance some-

[1] This experiment can be performed with a few cover-slips mounted on a stage-goniometer ; but it is shown to best advantage with a piece of silvery mica sufficiently thick to be perceptibly translucent to rays of normal incidence. It is necessary that the surfaces and substance of the plates should be free from dust particles, &c. This can be seen by making a pile of cover-slips the surfaces of which have been slightly smoked. Such a pile scatters the refraction-polarized rays, and is less transparent to rays of oblique than it is to rays of normal incidence. A pile of celluloid plates acts in the same way, owing to the fact that celluloid is crammed with dusty inclusions.

what complicated by twinning. Though triclinic in symmetry, amazon-stone is practically 'dichroic' in its pleochroism. In a basal cleavage plate the axis of maximum absorption is obliquely inclined, but the variation of absorption for vibration-directions parallel to the plate is very slight and almost inappreciable; and a basal plate appears practically colourless when examined in transmitted light of normal incidence. Now it may be assumed that the axis of maximum absorption, if not coincident with the **b** axis, is somewhere in its vicinity, and, like it, is inclined to both the faces (010) and (100). The intimate nature of the twinning, however, modifies matters. Thus in the albite-lamellae the axis of maximum absorption is for all practical purposes inclined at equal angles on opposite sides of the plane of composition in adjacent lamellae; hence with regard to this plane (010), the absorption is fairly symmetrical. Consequently, when the basal cleavage plate is tilted in such a way that the edge (001) : (010) is at right angles to the plane of incidence, the change from colourless to green is well seen whether the plate be tilted towards or away from the observer, which typifies the action to be expected in Case I (*b*). If the edge (001) : (010) be placed in the plane of incidence, a deep green is seen when the plate is tilted in one direction, but the plate remains colourless when tilted in the other direction, due presumably to the one-sided effect of the pericline-twinning.

Case II (*a*).—This case naturally yields a richer variety of effects than is to be observed in the two preceding cases. It includes such examples as basal cleavage plates of brown and markedly biaxial phlogopite, (010) cleavage plates of amazon-stone, and in some instances pink andalusite.[1]

A cleavage plate of brown phlogopite provides an extremely interesting example, in which the factor of paramount importance is the reflection-polarization of obliquely incident rays. As we have already seen in the experiment described on p. 4, if such a plate be held normal to the line of sight and examined in parallel rays, it shows the true facial colour of the plate. When tilted into an oblique position through a sufficiently large angle, and rotated in its own plane, it shows axial colours, chiefly due to the fact that the transmitted light is refraction-polarized. Hence we get the strong absorption effect when the axis of maximum absorption is lying in the plane of incidence, and the weak absorption effect when it is at right angles to that plane. This clearly cannot be a case of varying facial pleochroism, such as one might at first expect it to be;

[1] I am indebted to Professor G. A. J. Cole for calling my attention to a plate of pink andalusite in his collection which appears to come under this case.

for if it were, then the strong absorption effect would occur with the axis of maximum absorption at right angles to, instead of in, the plane of incidence.

Brown phlogopite exhibits this phenomenon in an exceptionally striking manner. Indeed, when a plate of it is examined in ordinary light, after the manner described above, it shows an axial pleochroism quite as pronounced as that seen when the plate is examined by means of a nicols prism or a dichroscope in light of normal incidence. In explaining this, one needs to remember the cleavage rifts, which are invariably present in the micas though not always conspicuous, and which intensify the reflection-polarization effect.

Case II (*b*).—As examples of this case we may take principal sections of deep-coloured tourmaline, and plates of green penninite and 'uniaxial' black biotite cut at right angles to the cleavage. In these, when a plate is held at right angles to the line of sight, we see a facial colour.

If in any of these instances the axis of least absorption be held horizontally, and the plate turned round this axis into an oblique position so that the ordinary ray is vibrating in the plane of incidence, the facial effect remains practically unchanged. At most, a slight diminution of intensity is observed, owing to impoverishment of the extraordinary ray by reflection-polarization.

If the axis of maximum absorption in the above instances be placed horizontally, and the plate turned round this axis into an oblique position so that the extraordinary ray vibrates in the plane of incidence, the facial colour darkens, and the effect approximates to that of the maximum-absorption axial value as the horizontal position is approached. With tourmaline in the latter position the effect is very pronounced, the light being almost completely, if not completely, absorbed, as would be expected.

In these instances, therefore, reflection-polarization exerts little or no perceptible effect, being overwhelmed by the influence of the relatively strong absorption of the ordinary ray. Pleochroic biaxial plates which come under this case act somewhat differently in so far as they are perceptibly 'trichroic' rather than 'dichroic'; but, like the instances above quoted, they would not be expected to show axial colours as the result of refraction-polarization.

5. Behaviour of pleochroic plates in a convergent beam.

Instead of examining pleochroic plates in parallel rays, we may use a convergent beam of ordinary light, such as may be obtained by placing one's eye close to the plate and looking at a broad expanse of sky, or by

using a microscope and examining with a system of converging lenses similar to that used for the observation of interference-figures.

By making the observation in this way, the effects of normal and oblique incidence are seen simultaneously. The phenomena thus obtained were originally studied in biaxial plates showing the emergence of the optic axes, and were later described as 'absorption-brushes' (Fr., houppes; Ger., Absorptionsbüschel). The term 'Absorptionsbüschel' is now used by the Germans to include also the effects seen in the uniaxial plates which we have referred to under Cases I (*a*) and I (*b*). Since, however, the term 'absorption-brushes' is inadequate for use in this wide sense, we shall use the name *absorption-figures* for the phenomena as a whole; but as the term *brushes* has become quite established in crystal optics as a translation of *houppes* and *Büschel*, we may perhaps use it freely as a convenient name for the colour-patches of an absorption-figure. The brushes of an absorption-figure should not be confused with Haidinger's 'polarization-brushes' (Ger., Polarisationsbüschel), as they are by some writers.[1] The two phenomena are quite independent of one another.

The consideration of absorption-figures follows naturally on that of the behaviour of pleochroic plates in parallel rays, and becomes more intelligible thereby. We shall see from a study of the behaviour of brown phlogopite, that reflection-polarization can play a conspicuous part in these figures, a fact which appears not to have been hitherto recognized.

We may, as in the case of parallel-ray effects, conveniently distinguish two kinds of plates, viz., those of Cases I and II. As a rule, plates cut at right angles, or approximately at right angles, to an optic axis of a pleochroic uniaxial crystal, fall under Cases I (*a*) and I (*b*); and in these there is no similarity between the absorption- and interference-figures in a convergent beam. On the other hand, plates cut at right angles to the acute bisectrix or an optic axis of a pleochroic biaxial crystal, fall under Cases II (*a*) and II (*b*); and for this reason they are as a rule capable of showing absorption-figures somewhat resembling those due to interference.

One remarkable exception to the rule stated above for uniaxial crystal plates normal to the optic axis is provided by amethystine quartz, which

[1] 'Textbook of Mineralogy,' by E. S. Dana, 1908, p. 219; also 'Mikroskopische Physiographie der petrographisch wichtigen Mineralien', H. Rosenbusch and E. A. Wülfing, 1904, vol. i, part 1, p. 341. On this point see further remarks in historical résumé, p. 25.

shows a considerable variation of absorption for vibration-directions at right angles to the optic axis. Plates cut at right angles to this axis, or approximately so, may show strong pleochroism in normally incident polarized rays, although in a principal section from the same crystal the pleochroism may be so slight as to be almost imperceptible. If a simply rotating portion of such a basal plate of amethyst be examined in convergent ordinary light, it will, if the pleochroism be sufficiently pronounced, show a fine absorption-figure somewhat resembling that of fig. 5, but uniaxial in form. If examined by means of a nicol, it will change as the nicol is rotated. In one instance observed by the writer the axial colours on the base were blue and colourless. When the short diagonal of the nicol lay along the axis of maximum absorption, a blue cross occupied the field, the intervening quadrants being comparatively colourless. When the nicol was turned through 90°, the cross was colourless, the intervening quadrants being coloured. In this latter position the absorption-figure seen was essentially an intensification of that seen in ordinary light; though with the nicol the interference-rings on the brushes were quite perceptible. This uniaxial absorption-figure for amethyst, which is unlike any that the writer has seen described for uniaxial crystals, can be fully explained after the fashion of the explanation given on p. 15 for the absorption-figure of brown phlogopite. Moreover, this observation furnishes a clear reason why in the interference-figure of a simply rotating amethyst between crossed nicols in white light, the central disc for one position of the nicols should give place to a bluish cross when the nicols are rotated.

Cases I (*a*) *and I* (*b*).—These do not call for much consideration, as the effects are usually inappreciable among minerals. Indeed, from what we have seen of the behaviour of these cases in parallel rays, we should not expect to get pronounced effects in a convergent beam. As already seen, even for large angles of incidence the variation is inappreciable in tourmaline and many biotites, and not very pronounced in penninite. Penninite, however, shows the effect fairly well in plates of suitable thickness, and may be taken as a good and ready illustration of Case I (*a*). The central and larger portion of the field is occupied by the green axial colour of the ordinary ray; whilst around the margin there is a halo of yellowish facial colour due to the fact that the marginal rays are sufficiently oblique to show a diminished absorption for the extraordinary ray.

In Case I (*b*), on the other hand, the central area shows less absorption than the margin. As previously remarked, this case is rarely met with

among minerals, and is usually illustrated by magnesium platinocyanide. Basal cleavage plates of amazon-stone show the marginal colour, but not as a continuous halo, for the reason already explained.

Pseudo-absorption-figures in mica.—The plates of biotite referred to above as showing no marginal halo are those comparatively free from cleavage rifts. If the observation be made on mica containing many rifts, preferably a colourless phlogopite (approximately uniaxial), it will be found to yield a well-marked halo in plates of suitable thickness (fig. 1). This marginal halo in silvery phlogopite is far more pronounced than that shown by penninite; but, as already explained in dealing with

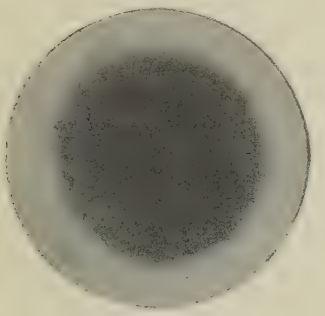


FIG. 1.—Pseudo-absorption-figure seen in 'uniaxial' mica containing numerous cleavage rifts, when examined in convergent ordinary light.

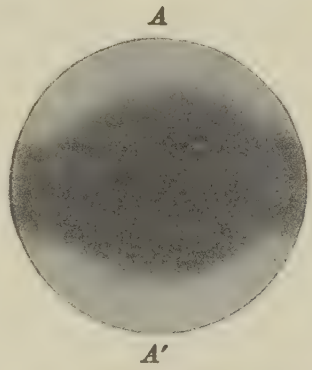


FIG. 2.—Pseudo-absorption-figure seen in the same plate, when examined in a convergent beam with one nicol. The short diagonal of the nicol lies along *A A'*.

the behaviour of such micas in parallel rays, this is not an instance of genuine pleochroism. It is essentially due to the action of the cleavage rifts, rather than to the absorptive effect of the mineral itself. The rays transmitted around the margin are refraction-polarized, as can be seen by examination with the analyser, when two areas of pronounced extinction appear at the margin where the plane of incidence is at right angles to the short diagonal of the analyser (fig. 2). This particular observation shows very effectively the refraction-polarization suffered by the obliquely incident rays in such a plate.

Cases II (a) and II (b).—These cases of absorption-figures include the familiar examples of 'Absorptionsbüschel' seen in plates of pleochroic biaxial minerals which show the emergence of one optic axis; and also

the still more interesting instances of plates showing the emergence of both optic axes. These latter were the instances originally observed by Sir David Brewster.[1] The examples described by him included blue topaz and mica in basal cleavage plates. Such plates, as we shall see below, are decidedly more complicated in their effects than those showing the emergence of only one optic axis, to which workers since Brewster have chiefly restricted their attention. The writer has been unable to find a detailed description or explanatory account of the absorption-figures originally noticed by Brewster in cleavage plates of mica, notwithstanding the fact that brown phlogopite provides perhaps the best absorption-figure to be seen among minerals, and is obtainable in cleavage plates of considerable size with a minimum of trouble.

The most important difference between Case II (*a*) and Case II (*b*) is that in the latter the rays emergent around the margin are likely to be absorption-polarized, as are those emerging from the centre of the plate; whereas in the former case the axial effect due to refraction-polarization gets a better chance of predominating over the facial effect, as we saw happened in the oblique position for parallel rays.

With regard to plates included in Cases II (*a*) and II (*b*), other than those showing the emergence of the optic axes, we need only remark that the effects to be observed are chiefly marginal and often inappreciable. In some instances, however, they are well marked. A principal section of dark tourmaline, for example, shows in ordinary light a bright band lying along the axis of maximum absorption, the margin of the field on either side being dark. This effect is clearly explained by what we saw of the behaviour of such plates in parallel rays.

With these remarks on the less interesting instances of Cases II (*a*) and II (*b*), we may now proceed to consider at greater length the more special and interesting examples of plates showing the emergence of the optic axes.

One of the best examples we can take of this case is a suitably thick basal cleavage plate of brown biaxial phlogopite, since it can be prepared with a minimum of trouble, and shows the emergence of both optic axes, the acute bisectrix being nearly normal to the plate. If we examine such a plate by placing it close to the eye and viewing it against a considerable expanse of sky or suitable source of artificial light, or better still by means of a microscope in a convergent beam of ordinary light, we see effects which are represented in fig. 3. In the central

[1] D. Brewster, Phil. Trans., 1819, vol. cix, p. 17.

area, the absorption-figure has a form which to some extent resembles that seen when the plate is examined between two parallel nicols so arranged that the short diagonals lie along the optic axial plane. The diameters lying in and at right angles to this plane are occupied by a pale yellow cross, the limbs of which are separated by four brushes of brownish colour which occupy the intervening quadrants. These brushes radiate outwards around two hyperbolic curves which have their apices in the traces of the optic axes. The two limbs of the cross which lie along the axis of least absorption of the plates, i. e. along the optic axial plane, expand towards the margin, where the colour becomes paler. The other two limbs, which lie at right angles to the optic axial plane, are more uniform in width, and do not reach the margin, having their ends surrounded by marginal areas of brownish colour which unite the

Fig. 3.—Absorption-figure of brown biaxial phlogopite, seen in convergent ordinary light.

Fig. 4.—Plan of vibrations to explain the effects represented in fig. 3. The black dots mark the points of emergence of the optic axes.

adjacent brushes. These effects can be clearly explained, keeping in mind what we have already seen of the behaviour of brown phlogopite in parallel rays, by reference to fig. 4, in which the vibration-directions of rays traversing various parts of the plate are represented.

Consider first the rays emerging along the axes b and c. At and near the centre, it is clear that these will show a facial colour. We have already remarked that a facial colour, in a strongly pleochroic plate, approximates closely to the colour of the least-absorbed ray. Hence we should expect that the rays emergent along the two axes referred to would show comparatively weak absorption, in so far as they yield

a facial colour, as they do in the central area. In the marginal portion of the field, however, the rays emergent along these axes are refraction-polarized, i. e. vibrating in the plane of incidence. Hence the rays emergent in the optic axial plane show a colour approximating to the c axial colour, whereas those emergent along the b axis show approximately the b axial colour in the marginal portion of the field.

Now consider the rays emergent along and in the vicinity of the hyperbolic curves diverging from the optic axes, as shown in fig. 3. These rays are also of two sorts, polarized at right angles to each other, but their absorption values are practically the same, being in each case something between the greater and lesser axial values of the plate. The light emergent at these points, therefore, instead of being made up of two very unequally absorbed rays, one of which suffers comparatively little absorption, is made up of two almost equally absorbed rays, both of which suffer substantial absorption. Consequently, these rays show a more marked absorption than do the rays emergent from the b and c axes. Rays emergent in the spaces between the hyperbolic curves and these axes suffer more or less absorption according as they are nearer the curves or the axes. In the marginal portion of the field the hyperbolic brushes are not appreciably affected by reflection-polarization, since practically only one absorption value is represented by them.

We find, therefore, a considerable variation in the rays of a convergent beam emergent from such a plate of phlogopite. Along the b and c axes in the central portion of the field the emergent rays are partially polarized by absorption, whereas in the marginal portion of the field they are refraction-polarized. Along and in the vicinity of the hyperbolic curves above referred to, the two sets of rays arising from double refraction have much the same intensity, and are therefore not to any appreciable extent either absorption- or refraction-polarized. In the intervening areas there is a gradual transition from one condition to another.

This condition of things explains, and is verified by, the effects observed when we examine the ordinary-light absorption-figure by means of a nicol prism—the analyser or polarizer. When the short diagonal of the analyser lies along the optic axial plane (c axis), there is a perceptible, though perhaps not very striking, difference in the effect. The facial colour along the b and c axes in the central area gives place to the c axial colour. At the same time the marginal axial colours due to reflection-polarization disappear, since the incident rays are now all vibrating in the axial plane. There is, however, less intensity at the

margin on the b axis than on the c axis, owing to reflection-polarization. These changes result in a sharpening of the contrast, and produce a more pronounced figure (fig. 5).[1] Moreover, we now get slight interference-effects on the hyperbolic brushes.[2]

If the short diagonal of the analyser be placed at right angles to the optic axial plane we get an effect which is represented in fig. 6. Along the b axis we get the b axial colour, which is fairly uniform throughout, as there is little or no reflection for these rays at the margin, since they are vibrating in the plane of incidence. Along the c axis (in the optic axial plane) the colour is darker, approaching extinction at and near the margin, owing to the fact that the incident rays are largely lost by

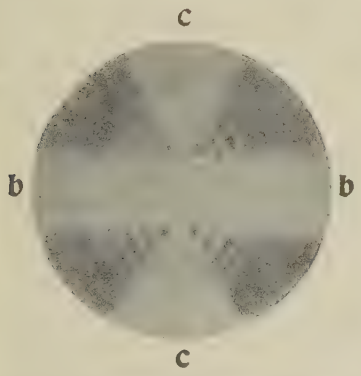


Fig. 5.—Absorption-figure of brown biaxial phlogopite in polarized light. The short diagonal of the nicol lies along the c axis.

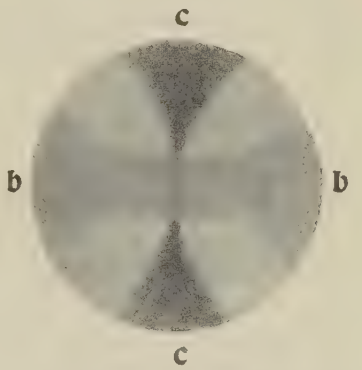


Fig. 6.—Absorption-figure of brown biaxial phlogopite in polarized light. The short diagonal of the nicol lies along the b axis.

reflection, since they are vibrating at right angles to the plane of incidence. In the intervening quadrants, the spaces previously occupied by the coloured brushes are now the brightest portion of the field, and as before they are marked by interference-effects.

It would be difficult to find another mineral, plates of which would yield an absorption-figure showing such strong marginal reflection-polarization effects as do cleavage plates of brown phlogopite.[3]

[1] It is for this reason that absorption-brushes can often be seen by means of a nicol when they are imperceptible in ordinary light. In very thin or weakly pleochroic plates the colour of the brushes becomes indistinguishable from the facial colour in ordinary light, though it may be quite perceptibly different from the extreme axial colours.

[2] For further remarks on these, see p. 19.

[3] This is the slightly ferriferous variety of phlogopite, showing a fairly pro-

Muscovite shows an absorption-figure, but the plates require to be fairly thick. The best way to see them in an ordinary muscovite is to make a pile of plates in which the optic axes of the various plates are coincident. By placing such a pile close to the eye and examining against the sky or a suitable source of artificial light, the figure seen is essentially similar to that of the phlogopite just described. In this instance, however, the convex sides of the brushes are remote from the acute bisectrix in consequence of the wider axial angle. On examining in polarized light a pile of muscovite plates tilted so as to show the emergence of one axis only, the extinction of the rays lying in the optic axial plane is very pronounced when the short diagonal of the nicol is at right angles to that plane. The absorption-figure of muscovite shows interesting variations on that of phlogopite, but these are easily explained as consequences of the weaker pleochroism and wider axial angle of the former.

The writer has not examined plates normal to an acute bisectrix, and showing the emergence of both optic axes, which would come under Case II (*b*). Indeed, it seems to be very rarely that an acute bisectrix, in a crystal with a small axial angle, is met with in conjunction with the other condition necessary for the exhibition of good absorption-figures.[1] It is presumably for this reason that absorption-figures are usually described only for plates showing the emergence of one optic axis, as in the familiar examples of andalusite and basal cleavage plates of green epidote. Both these minerals show good absorption-figures in ordinary light, the more easily studied case being that of epidote, because of its ready cleavage on the base, on which a more or less eccentric optic axis emerges. The figure for one optic axis can be well seen in brown phlogopite in ordinary light by holding a plate close to the eye and tilting it until one of the optic axes lies along the line of sight. It will be noticed that, under these conditions, reflection-polarization exerts

nounced axial angle, which occurs as a product of metamorphism in dolomitic limestones, &c. Even when the plates are not more than a millimetre in diameter, as often happens in these rocks, they are frequently pleochroic enough to show good absorption-figures under the microscope.

[1] Brewster described them in blue topaz and cordierite, in both of which the acute bisectrix is normal to the basal plane. The figure can be seen in ordinary brown Brazilian topaz, but only imperfectly, since owing to the wide axial angle the optic axes emerge near the margin of the field; and moreover, owing to the weakness of the pleochroism, it is necessary to use a nicol to see the figures clearly.

little visible effect upon the marginal portion of the figure, as would be expected from what we have already said.

The conditions presented by the emergence of only one optic axis are rather simpler than those obtaining when both axes emerge; and as the explanation of the effect follows much the same lines as that already given, we need not elaborate the matter further. It should be pointed out, however, that in the case of a single optic axis the figure is liable to be much less symmetrical than is the case with an acute bisectrix. This is particularly the case for variations of direction in the optic axial plane, especially when the axial values of c and a are appreciably different, and when the observation is made with a nicol having its short diagonal along the optic axial plane. In brown phlogopite these values are much the same, and the effects on either side of the optic axis in the optic axial plane are not perceptibly dissimilar. In epidote, however, the difference can be clearly seen.

6. Interference-effects in absorption-figures (idiophany).

The conditions under which interference-effects are observed in absorption-figures, and the agency by which they are produced, are matters about which there has been much discussion. The difficulty is one which appears not to have been satisfactorily settled.

In discussing this subject it is necessary to be precise as to the conditions under which the observation is to be made. It must be stipulated that the portion of the plate examined should be free from such twinning planes or other internal complications as would develop idiophanous interference-figures. The light used should not be appreciably polarized.[1] It has been argued in this connexion that the eye functions as an analyser, but its effects in the case of absorption-figures can be ignored as quite imperceptible. Of all these disturbing factors, the most important from a practical standpoint is naturally polarized light; and, as already mentioned, care should be taken to avoid its use when non-polarized light is required. These matters attended to, it will be found that an absorption-figure, seen in a convergent beam of ordinary light the axis of which is normal to the plate, shows no interference-effects;[2] whereas

[1] The mirror of an ordinary microscope is unable to produce any appreciable degree of polarization. The polarization so often noticed in the light reflected from the metallic mirror of a microscope is polarized skylight. It should also be noticed that some forms of artificial light are substantially polarized.

[2] According to Groth ('Physikalische Krystallographie,' 3rd edit., 1895, p. 159), andalusite shows the interference-rings in plates cut normal to an optic

when the observation is made by means of one nicol, either analyser or polarizer, interference-curves are seen. Why is this? When Bertin raised this question,[1] he answered it erroneously by saying that absorption-figures were due entirely to interference depending upon absorption-polarization in the plate itself. According to him, the action of a nicol was merely an intensification of what was already an interference-phenomenon ; 'il faut considérer les lames biaxes perpendiculaires qui donnent des houppes comme placées naturellement dans une mauvaise pince à tourmalines parallèles.'[2] In advocating this view Bertin seems to have had no supporters. The view is not without plausibility, though as a matter of fact it is quite erroneous.

It was rightly claimed by Mallard and others that the figure seen in convergent ordinary light was due to absorption alone. Mallard allowed, however, that interference-effects were obtained by using only one nicol; and these he explained by saying that, 'avant de passer de l'air dans le cristal, ou de sortir du cristal dans l'air, le rayon lumineux traverse une couche de très-faible épaisseur qui sert comme de couche de transition entre les deux milieux.' He assumes that this thin transitional layer, or atmosphere which surrounds a crystal, enables it to exert a polarizing effect upon the light which enters into and emerges from the crystal. Hence 'lorsqu'on place un polariseur derrière la lame, la surface antérieure de celle-ci joue le rôle d'analyseur, et que lorsqu'on place un analyseur derrière la lame, la surface postérieure de celle-ci joue le rôle de polariseur'.[3]

It is curious that Mallard should have considered it necessary to make such an assumption, and it seems quite unnecessary to put the matter as mysteriously as he did. The interference-effects to be accounted for are feeble. The rays yielding them are obliquely incident, and consequently must be, to a slight extent at least, refraction-polarized, both at incidence and emergence. If, therefore, we replace Mallard's assumption of a mysterious transitional polarizing layer by the fact of reflection-polarization, we get what is probably the correct explanation of the interference-effects observed when absorption-figures are examined by means of one nicol or its equivalent.

axis and examined in clear skylight; but this is presumably true only when the skylight is polarized.

[1] A. Bertin, 'Sur les houppes des cristaux polychroïques,' Bull. Soc. Min. France, 1879, vol. ii, pp. 54–66.

[2] A. Bertin, loc. cit., p. 66.

[3] E. Mallard, Bull. Soc. Min. France, 1879, vol. ii, p. 77.

It might, however, be claimed that, if this explanation be correct, the interference-effects should be seen in ordinary light. And if theoretically possible, why is it that, except perhaps to the eye of imagination, they are not as a rule perceptible? The reason for this is that reflection-polarization alone, for small angles of incidence, is too feeble to produce any appreciable interference; the effect becoming appreciable only when the figure is examined in a strongly polarized beam. At the best, however, the interference-effects seen with the microscope when only one nicol is used are feeble in comparison with those seen between two nicols, and are in many instances scarcely discernible. It is evident that if, on account of weak pleochroism, the plate has to be thick to show the absorption-figure, then the interference-rings may be too closely crowded to be perceptible. This is especially the case when, as in the case of epidote, the birefringence is considerable.

These interference-effects with one nicol only can be best observed by using the naked eye, and polarizing the light which traverses the plate by means of a principal section of tourmaline. In this way we get a large field and good illumination, and the effects can often be seen by this means when they are almost imperceptible under the microscope.

The explanation given above of the interference-effects, seen when absorption-figures are examined by means of a single nicol, has one important corollary. If the explanation be correct, it follows that interference-effects should also be visible when a non-pleochroic biaxial crystal plate, showing the emergence of an optic axis, is examined with one nicol; especially if the emergence can be secured on a plate so disposed as to produce a considerable degree of reflection-polarization. Fortunately this is a point which can be tested in the easiest possible manner.

Take a basal cleavage plate of quite clear and colourless topaz about two millimetres thick. Hold it close to the eye, and, with the optic axial plane in the plane of incidence, tilt it until one of the optic axes lies along the line of sight. The interference-figure for parallel nicols can then often be seen, when there is no appreciable degree of polarization in the skylight, without using a polarizer at all. It becomes quite pronounced when the skylight is appreciably polarized, and still more pronounced when the light entering the plate is polarized by means of a nicol or a tourmaline section.

If this observation be made on a plate of brown phlogopite, it will be found that the interference-effects are not appreciable in ordinary light. This may be due to some extent to the masking influence of absorption;

but it is presumably due in far greater measure to the fact that, owing to the smaller axial angle of the phlogopite, the angle of incidence is much smaller when an optic axis is lying along the line of sight, than it is in the case of topaz, and the amount of reflection-polarization consequently less.

These observations prove that the idiophanous interference-effects accompanying absorption-figures arise from reflection-polarization, as explained above; and that they are not peculiar to pleochroic plates. According to Voigt (see p. 27), non-pleochroic crystals should not yield these idiophanous interference-effects with one nicol only, let alone ordinary light; whereas pleochroic crystals should. It would, however, be difficult to find a pleochroic crystal showing a more pronounced idiophanous interference-figure than that referred to above as seen in a cleavage plate of colourless topaz.

Evidence of idiophanous interference-effects can also be very readily seen by examining a quartz-wedge with one nicol only, in parallel rays. The wedge should be tilted so as to effect reflection-polarization, and held with its vibration-directions diagonally to the plane of incidence and short diagonal of the nicol. Under these conditions the interference-bars on the wedge can be seen quite distinctly.

7. Historical résumé.

Observation in parallel rays.—There is a considerable amount of literature on the subject of pleochroism; but the only records which the writer has been able to find relating to the behaviour of pleochroic plates in parallel rays of variable incidence are those by Sir David Brewster and W. von Haidinger. Both deal with the case of mica. It is not clear exactly which variety was used by Brewster, but it was probably a biotite. Haidinger's mica was apparently a muscovite. Brewster remarks that 'another crystal (of mica) which in one direction was as transparent as ordinary specimens of olivine, would not admit, through a thickness of 0·1 of an inch, a single ray of the meridian sun on the 20th May, when it passed along the axis of the prism. The ordinary ray, which was entirely lost in one direction, became gradually visible in thin plates and at last of equal intensity to the other ray, as the ordinary light formed a greater angle with the laminae.'[1]

[1] D. Brewster, 'On the phenomena of dichroism,' Edinburgh Phil. Journ., 1820, vol. iii, p. 244.

'Haidinger is presumably referring to the same phenomenon when he remarks: 'Sieht man senkrecht durch die Basis A hin, so ist das Glimmerblatt, namentlich bei der Varietät von Utön (Winkel der Axen nach Grailich 72° 30′) bei einer gewissen Dicke, etwa von einer Linie, weniger durchsichtig, als wenn man schief dagegen hindurchsieht, weil bereits die Einwirkung des weniger absorbirten Tones der Axe *a* beginnt.'[1]

There can be little or no doubt that the phenomenon referred to by Brewster and Haidinger, in the passages cited above, is identical with the phenomenon described on p. 7 of the present paper as pseudo-pleochroism arising from the action of the cleavage rifts. It is perhaps not surprising that Brewster should have failed to recognize this fact, since he appears to have made his observation on a dark biotite, the intense pleochroism of which would lead one to expect that it might act in the way Brewster thought it should. We have seen, however, that black biotite shows practically no change when it is comparatively free from cleavage rifts; whereas phlogopite, which is almost colourless, shows a pronounced change when the cleavage rifts are numerous.

Haidinger had less reason for attributing the phenomenon to true pleochroism, since he appears to have made the observation on muscovite, which shows little or no pleochroism, especially in the sense implied by his observation.

Brewster seems to have been aware that minerals with a platy structure could act like a pile of plates. Indeed, it was in consequence of his observation that a cleavage plate of mica polarizes transmitted oblique rays more effectively than does a single glass plate, that he was led to construct a pile of plates in glass. It appears, however, that in his later work he failed to realize the bearings of this fact with regard to the pleochroism and pseudo-pleochroism of the micas in ordinary light.

The writer has not been able to find any record of the extremely interesting case of the behaviour of brown phlogopite in obliquely incident parallel rays.

Absorption-figures.—Brewster appears to have been the first to describe absorption-figures.[2] His first observations seem to have been made on basal cleavage plates of exceptionally fine blue topaz, but he describes the phenomenon in several other minerals, including mica and cordierite.

[1] W. Haidinger, Sitz. Akad. Wiss. Wien, 1854, vol. xiii, p. 312.

[2] D. Brewster, Phil. Trans., 1819, vol. cix, p. 17.

His observations on these figures were made with polarized light; but with regard to mica he remarks that the figure is seen quite distinctly in ordinary light. Although the mica which he refers to in this connexion was probably brown phlogopite, he seems not to have been aware that there was any difference between the figure seen in ordinary light and that seen in polarized light with the plane of polarization at right angles to the optic axial plane.

Brewster rightly regarded absorption-figures as features due to pleochroism, though he apparently made no observations on the presence of interference-effects when they are examined in polarized light. This is the more surprising because he had already recorded the fact that interference-effects could arise as a consequence of polarization by reflection and refraction.[1]

Herschel[2] made a study of the absorption-figures in biaxial crystals as described by Brewster, and explained them as due entirely to interference-effects. He was struck with the similarity of their form and position to those of the interference-figures seen with a polariscope. He inferred that the absorption-brushes resulted from the overlapping and consequent blurring of interference-rings; and this he attributed to 'a slight degree of confusion of structure' in the crystals. He tells us that the brushes ('cloudy fan-shaped spaces') can only be seen in 'limpid crystals' by examining them between a polarizer and analyser; and further, that they can be seen in a pleochroic crystal without polarizer and analyser, in consequence of the absorption-polarization of the plate itself, which enables it to act as an analyser towards the emergent ray. Erratic as is this explanation by Herschel, it is of some interest, especially on account of its near affinity to explanations which were advocated later, notably that by Bertin.

[1] See particularly 'On the affections of light transmitted through crystallized bodies', Phil. Trans., 1814, vol. civ, p. 203, where Brewster describes the interference-figure seen when ordinary light is sent obliquely through a plate of topaz, using an agate or a pile of plates as an analyser. I had already completed the observations embodied in the present paper before I found this record by Brewster, an earlier knowledge of which would have saved me much trouble. From the manner in which Brewster made his observation on topaz, it does not follow that polarization by reflection and refraction was the cause of the figure he saw, unless he took special precautions to see that there was no appreciable polarization in the 'ordinary light' which he used. His observation is, however, closely similar to that on colourless topaz which is given on p. 21 of the present paper.

[2] 'Light,' by Sir John F. W. Herschel; Encyclopedia Metropolitana, 1827, vol. iv, p. 557. The Encyclopedia as a whole was not published until 1845.

It was Herschel who applied the term 'idiocyclophanous'[1] to crystals which Brewster had described as showing interference-figures, in consequence of their self-polarizing action.

In 1844, Haidinger announced his discovery of the fact that when a beam of plane-polarized light falls on the eye, two small yellow 'Büschel' are seen lying parallel to the plane of polarization.[2] He pointed out that these can be seen not only in the nicols prism and dichroscope and certain polarizing plates of minerals, but also in polarized skylight. In his later papers these were referred to as 'Polarisationsbüschel'. Their cause was the subject of much discussion and very numerous papers by Haidinger and others. It appears to have been decided from the outset that these polarization-brushes were subjective phenomena; and we should have no need to refer to them here, had not Haidinger confused them in his first paper with the absorption-brushes originally described by Brewster. It was natural that, having apparently made his discovery before he had studied absorption-brushes, Haidinger should regard the latter as due to the same cause as his 'Polarisationsbüschel'. Certain micas, for instance, exhibited absorption-polarization, and he seems to have inferred that the 'Büschel' which they exhibited were due to this polarization.

Brewster, however, seems to have perceived from the first that Haidinger's brushes had nothing to do with absorption-brushes.[3] In his later papers, Haidinger also keeps the two phenomena quite distinct. In his papers on pleochroism in 1854 he refers to absorption-brushes not as 'Polarisationsbüschel', but simply as 'Büschel', describing the phenomena under the name of 'Idiostaurophanie', and attributing their discovery to Brewster.[4] As we have already mentioned, Haidinger's early confusion of 'Polarisationsbüschel' with 'Absorptionsbüschel' is still maintained in some modern textbooks.

The study of absorption-brushes was revived by Bertin,[5] whose ex-

[1] J. F. W. Herschel, loc. cit., p. 562.

[2] W. Haidinger, 'Ueber das directe Erkennen des polarisirten Lichts und der Lage der Polarisationsebene,' Ann. Chem. Phys. (Poggendorff), 1844, vol. lxiii, pp. 29–39.

[3] D. Brewster, 'On the coloured houppes or sectors of Haidinger,' Phil. Mag., 1859, vol. xvii, p. 323.

[4] See particularly W. Haidinger, 'Pleochroismus an einigen zweiaxigen Krystallen in neuerer Zeit beobachtet,' Sitz. Akad. Wiss. Wien, 1854, vol. xiii, pp. 306–331.

[5] See particularly A. Bertin, Bull. Soc. Min. France, 1879, vol. ii, p. 54, followed by a discussion, to which Mallard, Bertrand, and others con-

planation of them we have already referred to (p. 20). Bertin's explanation is, in part at least, a revival of Herschel's, as may be gathered from the quotation already given (p. 20) and his further statement that 'Les houppes sont formées par des segments d'anneaux, qui ne sont pas apparents parce qu'ils sont noyés dans la lumière naturelle'.[1] According to Bertin, absorption-brushes are only seen in pleochroic biaxial crystals.

Bertrand, in his contribution to the discussion appended to Bertin's paper, claimed that 'houppes' were also seen in uniaxial crystals; but the instances he referred to were those in which marginal modifications (halos, &c.) were to be observed under the conditions mentioned in Cases I (*a*) and I (*b*) of the present paper. These, as we have seen, are usually slight among minerals; and it was perhaps scarcely just on the part of Bertrand to regard these as 'houppes' in the sense in which Bertin and previous workers had used the term, though they might fairly be included with 'houppes' under the general name of absorption-figures.

It was in his excellent contribution to this discussion on Bertin's paper, that Mallard gave the true explanation of genuine absorption-brushes, i.e. those which depend upon the coexistence of emergent optic axes and absorption-polarization in the same plate. The explanation given in the present paper is essentially that adopted by Mallard. We have already (p. 20) noted the curious fact that Mallard, perceiving that the interference-effects which accompany absorption-brushes were due to polarization on incidence and emergence at the surface of the plate, made a false assumption to account for it, and overlooked the fact of reflection-polarization which renders his assumption unnecessary.

Liebisch[2] studied absorption-figures and described them as seen in various minerals in which they had been already observed by Brewster, Haidinger, Bertrand, and others. According to Liebisch, 'uniaxial' biotite yields an absorption-figure similar to that of penninite. According to the present writer's observations, however, 'uniaxial' biotite does not show genuine absorption-figures, but only pseudo-absorption figures, as described on p. 13 of the present paper.

tributed. Also A. Bertin, 'Sur les cristaux idiocyclophanes,' Ann. Chim. Phys., 1878, ser. 5, vol. xv, pp. 396–430.

[1] A. Bertin, loc. cit., p. 66.

[2] T. Liebisch, Nachr. Ges. Wiss. Göttingen, 1888. See also Liebisch's 'Physikalische Krystallographie', 1891, and 'Grundriss der physikalischen Krystallographie', 1896.

Absorption-brushes were studied by Tolstopiatow. His paper[1] is chiefly characterized by an exhaustive study of epidotes, of which he had an extensive collection. He preferred to make his observations on entire crystals rather than on plates, and he shows that the figures seen in this way in epidote are sometimes complicated by 'epoptic figures'[2] due to twinning, an effect similar to that described by Erman, who observed it in the complex twins of aragonite.[3] This complication due to twinning in epidote, to which Tolstopiatow devoted so much attention, had been already noticed by Klein,[4] and again by Voigt.[5] The fact that Tolstopiatow restricted his observations largely to epidotes, and examined them in such a way as to ensure a maximum of complication due to twinning, led him to exaggerate the importance of these complications, and made his general conclusions on absorption-brushes of little value.

The subject of absorption-figures has been treated mathematically by Voigt.[6] A later paper was published by Voigt in 1902,[7] and summarized by him in the Philosophical Magazine of that year.[8] According to his theory, light is not propagated through a pleochroic crystal in the same way as it is propagated through an 'ordinary or active transparent crystal'. In the former case he tells us that the transmitted light consists of 'two elliptic vibrations which have the same sense of rotation', whereas in the latter the 'two linear or two elliptic similar but crossed vibrations are of oppositely directed sense'. In the former case he informs us that his theory demands interference-rings when the observation is made in polarized light, whilst in the latter case his theory demands no interference-rings; and he claims, strangely enough, that 'experiment is in complete accord with this, and thus proves the

[1] M. Tolstopiatow, 'Notes sur les phénomènes des houppes,' Recherches Minéralogiques, Édition Posthume, Moscou, 1893.

[2] Erman's 'epoptic figures' are cases of 'idiocyclophany'. He was apparently unaware of Herschel's term, and of Brewster's earlier observations of similar effects.

[3] P. Erman, 'Ueber die epoptischen Figuren des Arragonits ohne vorläufige Polarisation,' Ann. Chem. Phys. (Poggendorff), 1832, vol. xxvi, pp. 302–307.

[4] C. Klein, 'Die optischen Eigenschaften des Sulzbacher Epidots,' Neues Jahrb. Min., 1874, pp. 1–21.

[5] W. Voigt, 'Erklärung der Farbenerscheinungen pleochroïtischer Krystalle,' Neues Jahrb. Min., 1885, vol. i, pp. 119–141.

[6] W. Voigt, loc. cit.

[7] W. Voigt, Nachr. Ges. Wiss. Göttingen, 1902, p. 48.

[8] W. Voigt, 'On the behaviour of pleochroitic crystals along directions in the neighbourhood of an optic axis,' Phil. Mag., 1902, ser. 6, vol. iv, p. 90.

existence, hitherto not established, of these pairs of waves with vibrations of the kind described'.[1]

It would appear, however, from the evidence considered in the present paper that reflection-polarization is a quite adequate cause of these interference-effects which are requisitioned by Voigt as the only experimental evidence available to support his theory; and if so, then Voigt is scarcely entitled to claim that his theory is supported by experimental evidence.

In concluding this historical résumé, one feels tempted to suggest that the use of the terms 'epoptic figures' and 'idiocyclophanous crystal' should be discontinued. Erman's 'epoptic figures' as seen in aragonite constitute a special case of 'idiocyclophany', and should be treated as such, as is done by Groth.[2] 'Idiocyclophany' is, however, a rather clumsy word, and was put forth somewhat apologetically by Herschel. Moreover, the contracted form 'idiophany', which has been used by Voigt and others, is decidedly preferable. Hence it seems desirable that one should use the terms 'idiophany' and 'idiophanous figures'[3] to signify the phenomenon of interference-effects arising in consequence of the polarizing action of the crystal itself, whether this be due to reflection-polarization at the surface, or to internal complications such as twinning lamellae.

8. Summary.

An examination of pleochroic plates in parallel rays shows that polarization by reflection and refraction is an important factor in determining the behaviour of the plates in some cases. Under certain conditions, which are exemplified in a remarkable manner by brown phlogopite, axial pleochroism arising from reflection-polarization is the predominant feature in the effects to be observed when the plate is examined in parallel rays of sufficiently oblique incidence. Reflection-polarization not only influences the phenomena to be observed in genuinely pleochroic plates; but under certain conditions, again exemplified by mica, it is capable of producing strong pseudo-pleochroism.

Since absorption-figures (Absorptionsbüschel) represent the effects of

[1] W. Voigt, Phil. Mag., 1902, ser. 6, vol. iv, p. 96.

[2] P. von Groth, 'Physikalische Krystallographie,' 3rd edit., 1895, p. 393.

[3] E. S. Dana apparently describes absorption-figures as idiophanous figures ('System of Mineralogy,' 6th edit., 1892, pp. 420, 497, and 518. Also 'Textbook of Mineralogy', by E. S. Dana, 1908, p. 219); but there seems to be no justification for the use of the phrase 'idiophanous figures' in this sense.

normal and oblique incidence simultaneously, it is desirable to consider them in the light of the behaviour of pleochroic plates in parallel rays. The two sets of phenomena fall naturally together under the head of the pleochroism of plates in light of variable incidence. Hence reflection-polarization is a factor to be reckoned with in dealing with absorption-figures, as is proved by the detailed consideration of the behaviour of brown phlogopite in a convergent beam. We have, therefore, to admit its action as a possible cause of the interference-effects observed when absorption-figures are examined in polarized light.

These interference-effects are theoretically inevitable as a result of reflection-polarization, whether the absorption-figures be examined in ordinary or polarized light. In practice, however, they are imperceptible with a convergent beam of ordinary light when the axis of the beam is normal to the plate; but they become perceptible when examined with a nicol. If the axis of the convergent beam of ordinary light is sufficiently inclined to the plate they may be seen without the agency of any polarization other than that arising by reflection and refraction at the surface of the plate.

If we make due allowance for this action of polarization by reflection and refraction, the explanation of idiophanous interference-effects demands no extraordinary assumption, such as that made by Mallard of a transitional polarizing atmosphere around crystals; or that made by Voigt with regard to the condition of the rays traversing the crystal. Both absorption-figures and idiophanous figures can be explained in a comparatively simple manner, on exactly the same basis as that employed for the explanation of the ordinary effects of pleochroism and interference.

Additional notes on Wood-tin.

(*With Plates I and II.*)

By J. H. Collins, F.G.S.

[Read November 15, 1910.]

IN my previous papers[1] I described and illustrated several examples of the concentrically banded and radiated varieties of cassiterite known as 'wood-tin', and stated that one very constant character of this variety was its rather remarkable opacity as compared with ordinary cassiterite, which is indeed somewhat exceptionally transparent considering its (often) deep coloration. I also noted the frequent occurrence of specimens of wood-tin encrusted with more or less distinct crystals of cassiterite, or traversed by fissures filled with such crystals, as indicating successive formation.

In such cases the sequence of events seems to be: (*a*) the deposition in successive layers of amorphous, perhaps colloidal cassiterite, which is usually very ferruginous; (*b*) the gradual development of a radial crystalline structure; (*c*) the formation of distinct crystals of cassiterite, quartz, tourmaline, chlorite, and other minerals in the shrinkage cracks or cavities which result from the lesser space occupied by the crystalline as compared with the colloidal cassiterite, these latter minerals being formed by the re-solution and crystallization of the originally impure tin deposit, and of materials dissolved from the surrounding rock or vein substance. These conclusions will, I think, be supported by the further illustrations which I now present in the form of photographs.[2]

1. Wood-tin from Goss Moor, St. Dennis, Cornwall (Plate I, figs. 1 and 2, Plate II, figs. 5 and 6).—This is obviously a fragment of vein-stone resembling in some respects those already figured in Plates VII to IX of my previous papers. Here are innumerable alternating layers of light-

[1] J. H. Collins, 'On some Cornish tin-stones and tin-capels,' Mineralogical Magazine, 1880, vol. iv, pp. 1–20, 103–116, with 12 plates; 1883, vol. v, pp. 121–130. Reprinted, 54 pp., with 12 plates, Truro, 1888.

[2] For these photographs I am indebted to my friend Mr. Jos. M. Coon of St. Austell.

and dark-coloured cassiterite and of quartz, in some cases moulded on pre-existing quartz crystals, in others forming finely banded linings to cavities ('eyes') as shown in Plate I, fig. 2, and Plate II, figs. 5 and 6.

2. Wood-tin (shot-tin) from the Burthy china-clay works, St. Enoder, Cornwall (Plate I, fig. 3, and Plate II, figs. 7, 8, and 9, which may be compared with figs. 1 and 2 of Plate X in my former papers).—The 'eyes', or 'shots', vary in size from $\frac{1}{10}$ to $\frac{1}{30}$ of an inch diameter, and they appear to have been originally developed as globules in a siliceous matrix. Fig. 7 shows one of the 'shots' surrounded by distinctly crystalline cassiterite, the product, as I think, of its gradual destruction. This section is not very accurately through the centre of the 'shot', consequently the concentric structure is not very well marked. In fig. 8 the section is very nearly central, and many of the concentric 'shells' of which it is composed are plainly visible. The centre of this particular body, when examined under a higher power, is seen to consist of a group of quartz crystals, together with some tourmaline needles and a small quantity of opaque brown matter, probably oxide of iron, the whole being surrounded by an irregular aureole of similar substance. There is then an interspace occupied by quartz, which is succeeded by the first of a series of dark rings, and from which project inwardly many minute acicular crystals of cassiterite. Then follow many alternations of darker and lighter bands, with at least one distinctly quartz-filled interspace, the whole being crossed by fine radiations. Outside all is distinctly crystallized cassiterite in long prisms (fig. 9), which finally meet similar projections from other 'shots', leaving irregular interspaces, as seen in Plate I, fig. 3; also in Plate X, fig. 4, of my former papers.

3. Wood-tin (shot-tin) from Wheal Kitty, St. Agnes, Cornwall (Plate II, fig. 14).—In this section the original spherules are broken up, probably by subsequent stresses, partial solution, and re-crystallization. The specimens from Wheal Kitty and other St. Agnes localities recently examined by Messrs. Flett and Scrivenor afforded similar evidence: 'In some slides the felted masses of brown tourmaline are seen to be traversed by veinules of quartz bearing blue tourmaline. . . . In the specimen from Wheal Kitty dense masses of very minute and pale blue tourmaline prisms were found mingled with minute flakes of chlorite. . . . There can be no doubt that part of the blue tourmaline crystallized before the cassiterite'[1] (p. 77). It is in such complex crystallizations

[1] J. S. Flett and J. B. Scrivenor, Mem. Geol. Survey, 'Geology of Newquay,' 1906, pp. 76, 77.

that we often find traces of 'shots' of tin-ore, which have evidently been broken up and transformed as described above.

4. Wood-tin from Mexico (Plate II, figs. 10 to 13).—This is a remarkably opaque, reddish-brown substance. The specimen described was one of many rounded alluvial grains, probably from Durango; while Plate I, fig. 4, is a photograph in natural size of a quite similar substance from a vein, showing distinct globular masses, which have a structure precisely similar to that now to be described. In the lower part of fig. 10 the finely banded concentric structure of the interior of the rounded masses is seen, and near the top another series of bands. Between these the almost opaque mass is seen full of radial fissures,—shrinkage-cracks, apparently—which do not traverse the fine alternating bands. In figs. 11 and 12 some of the lighter bands are seen to be composed of bundles of acicular crystals, while fig. 13 shows the more minute 'vandyked' structure visible under a comparatively high power (magnified 110 diameters). The lack of transparency makes it difficult to apply still higher powers with advantage, and it must be admitted that the final 'resolution' of this peculiar structure has not yet been reached.

5. Wood-tin from Mina del Diablo, Durango, Mexico (Plate II, fig. 15).—The close association of cassiterite and haematite in some of the tin-stone from this locality was long ago noted and described by L. V. Pirsson.[1] His conclusion was thus stated: 'It would seem as if the two minerals had been formed simultaneously and the hematite having a greater tendency to crystallize than the cassiterite had assumed its crystal boundaries without regard to the latter.' This was probably the true explanation of the origin of the compound and well-formed hexagonal crystals figured by him. But in the same stones there are many minute, translucent, red or brown, mamillary globules of wood-tin showing concentric banding and slight radial structure, which have evidently been deposited upon nearly or quite opaque haematite crystals; the whole being surrounded by a quartz matrix showing traces of striped felspars. One of these radiated and concentric groups of peculiar form is shown in fig. 15.

It seems likely enough that the original deposit was a gelatinous mass of mingled oxides of tin and iron, and also that there was some simultaneous crystallization, as suggested by Pirsson. Yet it would seem that even after much of the tin and perhaps all the iron had crystallized, enough tin oxide remained to furnish numerous new globular deposits.

[1] L. V. Pirsson, Amer. Journ. Sci., 1891, ser. 3, vol. xlii, p. 407. See also F. A. Genth, Proc. Amer. Phil. Soc., 1887, vol. xxiv, p. 23.

The marked tendency of oxide of tin to form botryoidal or globular aggregates is evident in the fine specimen from Tregoss Moor which is figured in Plate VIII of my former papers, and is now in the Truro Museum. It is also evident in two specimens in my possession from Wheal Metal, Breage, Cornwall, and still more strikingly in the Mexican[1] specimen figured here in Plate I, fig. 4.

These botryoidal forms of a mineral usually occurring in a highly crystallized condition should be considered in connexion with botryoidal or stalactitic forms of silica, phosphate of lime, pyrites, blende, galena, chalcopyrite, &c.[2] I would suggest that all have somewhat the same relation to the corresponding crystalline forms as chalcedony (and perhaps opal, except as regards its contained water) has to rock-crystal. I am also disposed to believe that all have been deposited somewhat rapidly from hot and often impure solutions at moderate depths and under little pressure. Whether such rapidly deposited colloidal forms are finally changed into crystalline forms depends no doubt upon their subsequent experiences, of varying pressure, the operation of circulating solutions, and the like. But such evidence as I have so far been able to acquire by the use of the microscope leads me to think that they are—and in particular that wood-tin was originally (and is still largely)—non-crystalline. Furthermore, I think this conclusion receives some support from the fact that wood-tin is sometimes soluble to a remarkable degree in hydrochloric acid.[3]

In conclusion, let me offer these beautiful figures and somewhat crude suggestions for the consideration of those more competent than myself to investigate chemically and optically the problems here indicated.

[1] A very fine specimen of dark colour, probably from Mexico, has recently been acquired by the British Museum as a bequest from the late Mr. F. Tendron, and there is a very similar specimen in the Ludlam collection at the Museum of Practical Geology in Jermyn Street, London.

[2] Botryoidal or stalactitic forms of all these substances were exhibited by the author in illustration of his paper.

[3] See J. H. Collins, 'On the assay of tin and on the solubility of cassiterite,' Trans. Inst. Mining and Metall., 1903-4, vol. xiii, pp. 485-486.

[*Explanation of Plates*, p. 34.]

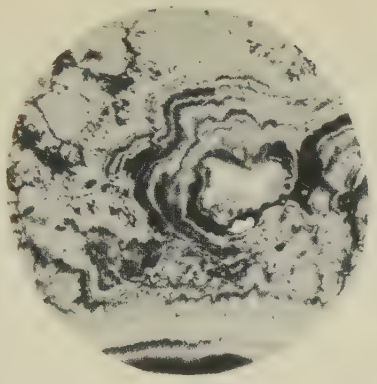
Explanation of Plates.

Plate I.

Fig. 1. Wood-tin from Goss Moor, St. Dennis, Cornwall (slightly enlarged).
,, 2. Part of fig. 1 (×2).
,, 3. Wood-tin (shot-tin) from the Burthy china-clay works, St. Enoder, Cornwall (×5).
,, 4. Botryoidal wood-tin from Mexico, probably Durango (actual size).

Plate II.

Fig. 5. Part of fig. 1 (×7).
,, 6. Another portion of same (×7).
,, 7. Wood-tin from the Burthy china-clay works, St. Enoder, Cornwall (×7).
,, 8. ,, ,, ,, (×9).
,, 9. ,, ,, ,, (×40).
,, 10. Wood-tin from Mexico, probably Durango (×9).
,, 11. ,, ,, (×9).
,, 12. ,, ,, (×33).
,, 13. ,, ,, (×110).
,, 14. Wood-tin (shot-tin) from Wheal Kitty, St. Agnes, Cornwall. Here the spherules are much broken up (×28).
,, 15. Wood-tin from Mina del Diablo, Durango, Mexico (×50).



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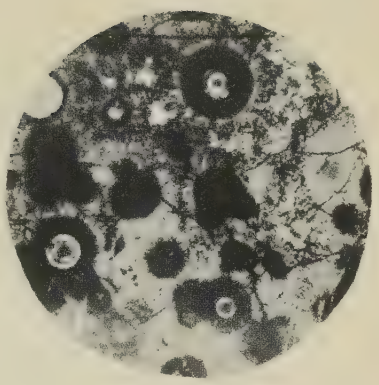

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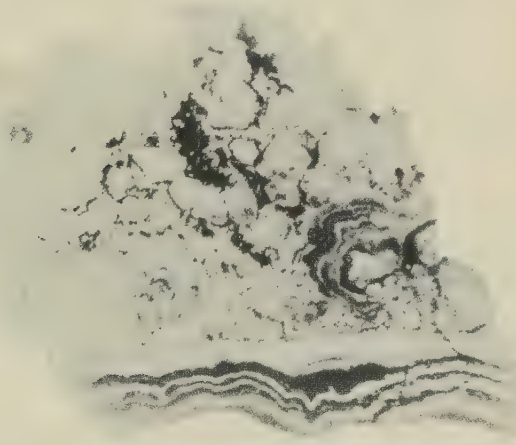

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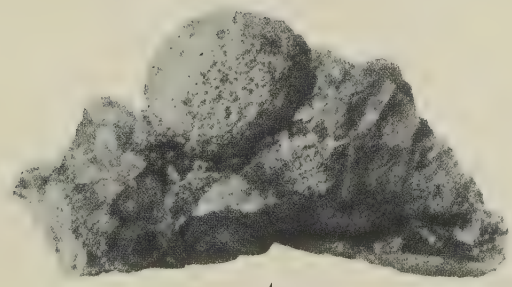


4

J. H. Collins: Wood-tin.

Communications from the Oxford Mineralogical Laboratory. No. XVIII.

On the composition of a stone from the meteoric shower which fell at Dokáchi, Bengal, on October 22, 1903.

By H. E. Clarke, B.A., B.Sc.
Jesus College, Oxford,
and H. L. Bowman, M.A., D.Sc.
Professor of Mineralogy in the University of Oxford.

[Read January 25, 1910.]

Introduction. (H. L. B.)

On October 22, 1903, a considerable shower of meteoric stones occurred in the neighbourhood of the village of Dokáchi, situated near the mouth of the Ganges, in the Dacca district of Bengal. Seven of these stones, which had been obtained from natives on the spot by Mr. H. E. Stapleton, M.A., of St. John's College, Oxford, Inspector of Schools in the Dacca district, were recently presented by him to the Oxford Museum.

The circumstances attending the fall have already been described by Dr. L. L. Fermor,[1] who has also given a description of the distribution and external characters of twenty-four stones and fragments (among them those now at Oxford), which had been transmitted to the Geological Survey Office, Calcutta.

Inquiries made by the Indian Geological Survey showed that nearly a hundred stones, of various sizes, had been found in Dokáchi and the neighbouring villages, but that most of these had been carried away by the natives and had not been recovered. Only twenty-four stones and fragments are stated by Dr. Fermor to have reached the Geological Survey, varying from 1570·99 grams to 0·73 gram, and amounting in

[1] L. L. Fermor, Records Geol. Survey, India, 1907, vol. xxxv, pp. 68–78.

all to 3838 grams. It was estimated that in the aggregate the stones which fell 'must have been numbered by the hundred'.

In 1907, the Geological Museum at Calcutta possessed fifteen fragments and slices, weighing in all 2057·35 grams, while the next largest amount (622·55 grams) was in the British Museum (comprising one large stone of 594·04 grams, and a fragment weighing 28·51 grams).

The greater portion of the shower seems to have fallen in and about Dokáchi, from which village three of the largest stones, weighing together 2360 grams, were obtained; and this name is therefore applied by Dr. Fermor to the whole shower.

The stones presented by Mr. Stapleton to the Oxford Museum were found in the villages of Dakhin Paiksha, Bibandi, Háriya, and Rána, and weighed in all 584·23 grams. Their weight and sources are as follows:—

Oxford Registered No.	Indian G. S. Museum Registered No.	Weight in grams.	Found at.
12952	240 C7	486·18	Dakhin Paiksha.
12953	240 F4	9·03	Bibandi.
12954	240 F5	1·97	,,
12955	240 F6	1·76	,,
12956	240 F7	1·32	,,
12957	240 H	66·18	Háriya.
12958	240 J	17·79	Rána.

These are all complete stones, covered with crust, or only slightly chipped. The largest of them was for some time worshipped by the natives, and still shows traces of the vermilion paint with which it was then smeared.

In his paper Dr. Fermor states that most of the stones he examined are more or less completely covered with a dull to slightly glossy crust, varying in colour from brownish-black to black, sometimes with greyish-white or rusty patches. The crust is usually comparatively smooth, but often exhibits numerous small pimples and ridges of a shining black colour, which impart a slightly polished appearance to stones on which they occur in any abundance. One stone shows crust of two ages, indicating the occurrence of a fracture early in its passage through the atmosphere. Some of the stones show well-marked pittings or 'thumb-marks'; and some are traversed by thin black veins, which are seen, where broken open, to be polished and slickensided. On a fresh fracture the stones are pale ash-grey, and a lens reveals

darkish-grey chondrules set in a grey and white matrix, and abundant yellowish-white metallic particles of nickel-iron (or ? troilite—H. L. B.).

The specific gravity of three stones examined by Dr. Fermor was 3·62 to 3·65.

Physical Characters of the Rána Stone. (H. L. B.)

The stone No. 12958, weighing 17·79 grams, which fell in Rána, has been cut across, and four thin sections prepared, each having an area of about 20 × 16 mm. One of the two remaining portions of the stone was used for the analysis described below, while the other portion (5·22 grams) remains in the Oxford Museum.

The cut surface of the stone is grey, with a few brownish crystals of iron-stained olivine and fairly numerous bright grains of iron which show only very slight traces of rusting. A little troilite is also visible with a lens, forming minute, granular patches. A lens shows also a few rounded chondrules, mostly of a darker grey than the matrix. On a small broken surface on this stone, one or two dark-grey rounded chondrules project, but this is not noticeable on the chipped corners of other stones.

The crust on the Rána stone is black, while that on the other Oxford specimens is brownish. The shining pimples and ridges, mentioned by Dr. Fermor, appear to be due to projecting granules of nickel-iron.

Under the microscope, the matrix is seen to be a rather finely granular mixture of olivine and bronzite, with irregular grains of nickel-iron and traces of troilite. Chondrules are present, though not very numerous; they consist mostly of granular or porphyritic olivine, and are round or oval in form; a few are composed of radial-fibrous bronzite, and there are one or two examples of monosomatic olivine chondrules with parallel glass-inclusions, of the type shown in Plates IX and X, figs. 5 and 6, of the authors' paper on the Chandakapur stone.[1] Some of the prisms of bronzite show traces of a twin-lamellation like that described on p. 355 of the same paper (β- and γ-bronzite).

The stone examined appears to be referable to the group of Intermediate Chondrites (Ci) of Tschermak, but the veins mentioned by Fermor suggest that some at least of the other stones should be classed as Cia.

[1] H. L. Bowman and H. E. Clarke, 'The structure and composition of the Chandakapur meteoric stone,' Mineralogical Magazine, 1910, vol. xv, pp. 350-376.

Chemical Analysis of the Rána Stone. (H. E. C.)

§ 1. The methods to be adopted in the chemical analysis of meteoric stones have been described in detail by Mr. Fletcher in his papers on the meteorites of Makariwa[1] and Zomba,[2] and by the present authors in their account of the Chandakapur stone.[3] The procedure followed in the present work was, in general, the same as that given in the last communication, and may be sufficiently understood from the notes which follow, with the help of the table on p. 46.

§ 2. It may be noted here that, of the minerals, which occur in most meteoric stones (in addition to the silicates and nickel-iron, and the rust which is commonly present owing to the oxidation of the latter), troilite (FeS) and schreibersite (Fe_2NiP) are unique in containing sulphur and phosphorus, respectively. Their amounts can therefore be deduced directly from determinations of the sulphur and phosphorus present.

Magnetite (Fe_3O_4) is separated from rust with the help of the magnet, and since it is unaffected by mercuric-ammonium chloride solution it is readily separated from the metallic alloys, which are dissolved by that reagent.

Chromite ($FeCr_2O_4$) is unaffected by hydrochloric acid, which gelatinizes olivinic silicates, and it may be separated from silicates not so gelatinized (e. g. pyroxenes and felspars), by the action of fused sodium and potassium carbonates, which decompose the silicates, but leave chromite almost unattacked.

The Material.

§ 3. The stone which fell at Rána weighed, before slicing, 17·79 grams, and was completely covered with crust. The larger of the two portions which remained after the cutting of the sections (weighing 7·2891 grams) was used for the analysis, and weighed 6·8841 grams after removal of the crust [A].[4] It was crushed as finely as possible, and the plentiful metallic grains, some of which were as much as 2 mm. in diameter, removed with a magnet. The 'attracted' material so obtained weighed 2·5809 grams; the 'unattracted' material, 4·3016 grams. The weight actually used for the analysis was, therefore, 6·8825 grams, the loss during crushing and magnetic separation being 0·0016 gram.

[1] L. Fletcher, Mineralogical Magazine, 1894, vol. x, p. 287.
[2] L. Fletcher, ibid., 1901, vol. xiii, p. 1.
[3] H. L. Bowman and H. E. Clarke, loc. cit.
[4] The letters in square brackets refer to the tabular summary on p. 46.

Extraction of the Material [A] with Mercuric Solution.

§ 4. The 'attracted' and 'unattracted' portions of [A] were separately treated with mercuric-ammonium chloride solution (cf. vol. xv, p. 360), in flasks through which a slow stream of coal-gas, washed with water, potash, and sulphuric acid, was maintained. The 'attracted' material was extracted with fourteen portions of mercuric solution, each of 50 c.c., and the 'unattracted' material with nine such portions. The process of extraction occupied seventeen weeks, at the end of which time the mercuric residues [A′] were practically free from nickel-iron.

An appreciable amount of rusting of the metallic alloy, as a result of its frequent exposure to air, must undoubtedly have taken place during the extraction. As, however, the stone was at first in a very fresh condition, the rust found may be taken to be wholly due to the oxidation of metal which would otherwise have passed into the mercuric extracts.

The extracts yielded in all 1·5807 grams of Fe_2O_3 and 0·0791 gram of (Ni,Co)O:[1] they contained also traces of copper, manganese, and zinc. The nickel and cobalt were separated by the use of dimethylglyoxime, as recommended by Brunck,[2] and the ratio of their weights was found to be 5·76 : 1.

§ 5. During the extraction of the Chandakapur stone with mercuric solution, the ratio of nickel to iron passing into solution was observed to increase in the successive extracts.[3] Mr. Fletcher attributed the occurrence of a similar phenomenon, observed in the course of his investigation of the stones of Zomba and Makariwa, to the presence of a stable alloy containing 38·5 per cent. of nickel,[4] and this proportion was approached in the later extracts of Chandakapur. No regular variation of this kind has, however, been observed during the treatment of the Dokáchi meteorite with the mercuric solvent; but it seems probable that the abrupt changes which were here observed in the proportion of nickel to iron in successive extracts, may have been due to a distribution of the different constituents in the metallic grains, such that one alloy would for a time screen another, richer or poorer in nickel, from the action of the solvent.

[1] viz.: from the 'attracted' portion 1·5004 grams Fe_2O_3; 0·0749 gram (Ni, Co)O.
" 'unattracted' " 0·0803 gram " ; 0·0042 " "

[2] O. Brunck, Zeits. f. analytische Chemie, 1908, vol. xlvii, p. 163.

[3] H. L. Bowman and H. E. Clarke, loc. cit., p. 363.

[4] L. Fletcher, Mineralogical Magazine, 1908, vol. xv, p. 149.

Reduction of Rust, etc., in Hydrogen.

§ 6. A portion [B], weighing 3·5139 grams, of the mixed dry metal-free mercuric residues [A′] was treated with the magnet, and the two portions so obtained (viz. 0·0603 gram 'attracted', and 3·4536 grams 'unattracted') heated for several hours to dull redness in a stream of hydrogen. By this means rust, magnetite, and schreibersite were wholly, and troilite partly, reduced to the metallic state. The reduced products were then separately extracted with mercuric solution. The extracts from the 'attracted [B]' yielded 0·0428 gram of Fe_2O_3 and traces only of NiO; those from the 'unattracted [B]' yielded 0·2389 gram of Fe_2O_3 and 0·0026 gram of (Ni,Co)O. The ratio Ni : Co was here approximately 9 : 1.

§ 7. In order to decide to what extent the troilite had been reduced by the hydrogen, it was necessary to know the amount of sulphur contained in that portion [B] of the mixed mercuric residue [A′] which had been submitted to reduction, and the amount of sulphur still remaining in the mixed mercuric residue [B′]. For this purpose portions of [A′] and [B′] weighing respectively 1·0241 and 1·1197 grams were taken, and the sulphur contained in them determined in the manner described by Mr. Fletcher.[1] From the results it was calculated that the amount of sulphur contained in [B] was 0·0554 gram before, and 0·0137 gram after the reduction, and that the troilite reduced was equivalent to 0·1042 gram of Fe_2O_3.

§ 8. If the whole of the troilite had been present in the 'attracted [B]', the latter must have weighed at least 0·1146 gram, and the Fe_2O_3 obtained from it as described in § 6 at least 0·1042 gram; whereas the 'attracted [B]' actually weighed only 0·0603 gram, and yielded 0·0428 gram of Fe_2O_3. The deficit cannot be due to incomplete separation of the magnetic portion of the material [B], for this process was carried out as thoroughly as possible, the dry powder being repeatedly worked through in small portions at a time, until the magnet ceased to collect any further particles. It is therefore most probable that the troilite was wholly present in the 'unattracted' portion, and that about three-fourths of it, yielding 0·1042 gram of Fe_2O_3, was reduced to metallic iron on heating in the stream of hydrogen. The iron obtained by reduction of the 'attracted [B]', which yielded 0·0428 gram of Fe_2O_3, must then have been due to magnetite, while the iron obtained by the reduction of the 'unattracted [B]', which yielded 0·2389 gram of Fe_2O_3, was due to

[1] L. Fletcher, Mineralogical Magazine, 1894, vol. x, p. 298.

rust and troilite, the former accounting for 0·1347 gram and the latter for 0·1042 gram of Fe_2O_3. The nickel of the 'unattracted [B]' must also probably be attributed to oxide formed during the extraction, and should be considered as part of the metallic content of the meteorite.

Estimation of Phosphorus.

§ 9. A determination, made on that portion of metal-free residue [A′] which had served for the estimation of sulphur, showed that [A′] contained only 0·0018 gram of phosphorus. As this material must have contained the whole of the schreibersite, the value given represents the total phosphorus in 6·8825 grams of the stone.

Composition of Stone as determined by the foregoing Treatment.

§ 10. The following table gives the amount of nickel-iron, troilite, schreibersite, and magnetite in the portion of the meteorite submitted to analysis (6·8825 grams):—

	Grams.	Grams.
Metallic Iron	1·1065	1·2008
Iron from rust	0·0943	
Metallic Nickel	0·0670	0·0704
Nickel from rust	0·0034	
Metallic Cobalt	0·0121	0·0125
Cobalt from rust	0·0004	
Magnetite		0·0763
Troilite		0·2821
Schreibersite		0·0117

Percentage composition of the Nickel-Iron.

§ 11. The metallic alloy present in the meteorite must thus have the following mean percentage composition:—

Fe	93·5
Ni	5·5
Co	1·0
Cu	distinct trace
Mn, Zn	traces
	100·0

Separation of Silicates.

§ 12. The combined mercuric residues [B′], which contained the chromite and unreduced troilite and the silicate minerals, weighed 2·3191 grams, and 1·1994 grams of this weighed, after gentle ignition to remove the mercury, 1·1920 grams. This latter portion was treated successively with hydrochloric acid and sodium carbonate solution, as described in the previous paper (p. 366). The sulphur determinations (§ 7) indicate that this portion would contain 0·0194 gram of unreduced troilite, and from this source the acid solution would afford 0·0177 gram of Fe_2O_3 on precipitation.

The chromite and silicates unattacked by the reagents accounted for 0·5899 gram, and the troilite together with the attacked silicate must therefore have amounted to 0·6021 gram.

Analysis of the 'Attacked' Material and 'Unattacked' Residue.

§ 13. The constituents of the attacked material (other than alkalis) were then determined. For the estimation of the alkalis a separate portion of the residue [A′] was taken, and the results are given in § 16.

§ 14. The greater part (viz. 0·5843 gram) of the unattacked residue was fused with sodium and potassium carbonates and submitted to the ordinary processes for the analysis of silicates. The material was completely decomposed during the fusion, but a small amount of chromium found in the melt is probably to be attributed to chromite, which is slightly attacked by fused alkali carbonates.

§ 15. The following are the results obtained :—

(a) *Attacked Material.*
(0·6021 gram.)

Troilite	... ...	0·0194	gram.
Silicates	SiO_2	0·2068	,,
	FeO	0·2197	,,
	CaO	0·0086	,,
	MgO	0·1346	,,
	Al_2O_3	0·0039	,,
	Cr_2O_3	nil	
	NiO	0·0014	,,
	Na_2O, K_2O	not determined	

(b) *Unattacked Residue.*

(0·5899 gram.)

A portion of this, weighing 0·5843 gram, gave: –

Chromite	...	...	0·0034 gram.
Silicates	SiO_2	...	0·3358 ,,
	FeO	...	0·0867 ,,
	CaO	...	0·0204 ,,
	MgO	...	0·1263 ,,
	Al_2O_3	...	0·0030 ,,
	NiO	...	0·0013 ,,
	Na_2O, K_2O	...	not determined

Estimation of Alkalis.

§ 16. Two portions of the material [A′] were taken for the determination of alkalis. These weighed 1·0085 grams and 0·9578 gram; and, after gentle ignition, 0·8889 gram and 0·8430 gram respectively.

Exactly half of the first portion, on treatment by Lawrence Smith's method, yielded 0·0120 gram of mixed alkali chlorides; and this, on treatment with chloroplatinic acid, gave 0·0063 gram of K_2PtCl_6. The other half of the material was lost during a second similar determination.

The portion weighing 0·8430 gram was treated with hydrochloric acid, in the manner adopted for the separation of the silicates. The unattacked residue, so obtained, yielded by the same method 0·0174 gram of mixed alkali chlorides, which by treatment with chloroplatinic acid gave 0·0096 gram of K_2PtCl_6.

From these results, after correction for alkalis present in the Lawrence Smith mixture, it is found that, of the portion (0·8430 gram) taken, the material attacked by acid contained 0·0058 gram of Na_2O and 0·0069 gram of K_2O, while the unattacked material contained 0·0072 gram of Na_2O and 0·0018 gram of K_2O.

Percentage Composition and Nature of the Silicates.

§ 17. The following tables give the percentage composition of the silicates, as calculated from the values given in §§ 15. 16, after deducting the troilite and chromite.

In the third column is shown the weight of oxygen contained in the silica and the several basic oxides combined with it.

(a) *Silicates attacked by Acid.*

(0·5827 gram.)

The material attacked by acid (0·6021 gram) contained 0·5827 gram of silicates, of the following composition:—

		Oxygen. Grams.	
SiO_2	35·49	0·1193	
FeO	37·72	0·0488	
CaO	1·48	0·0024	
MgO	23·10	0·0538	
Al_2O_3	0·67	0·0019	0·1088 gram.
Cr_2O_3	nil	—	
NiO	0·26	0·0003	
Na_2O	0·99	0·0015	
K_2O	0·16	0·0001	
	99·87		

(b) *Silicates unattacked by Acid.*

(0·5809 gram.)

The portion of the material unattacked by acid, which was analysed (0·5843 gram), contained 0·5809 gram of silicates, of the following composition:—

		Oxygen. Grams.	
SiO_2	57·60	0·1791	
FeO	14·87	0·0192	
CaO	3·51	0·0058	
MgO	21·68	0·0505	
Al_2O_3	0·51	0·0014	0·0794 gram.
NiO	0·22	0·0003	
Na_2O	1·23	0·0019	
K_2O	0·31	0·0003	
	99·93		

The 'attacked' silicates consist for the greater part of olivine approximating in composition to $Fe_2SiO_4 . Mg_2SiO_4$, but containing some calcium. The proportion of iron to magnesium is remarkably high, being comparable with that in the olivine of Bandong (Cwb) and Kakowa (Cga), quoted by Cohen,[1] in which the FeO amounts to 33·49 and 42·23 per cent. respectively.

The 'unattacked' silicates consist mostly of a pyroxene, rich in iron but with very little alumina, and perhaps a little felspar. The latter mineral has apparently suffered attack during the separation of the silicates, as a portion of the alkalis and alumina appears in the attacked material. The pyroxene with nearly 15 per cent. of FeO would (according to Cohen's usage[2]) be on the border-line between bronzite and hypersthene.

General Composition of the Stone.

§ 18. It follows from the above that the general composition of the stone may be expressed as follows:—

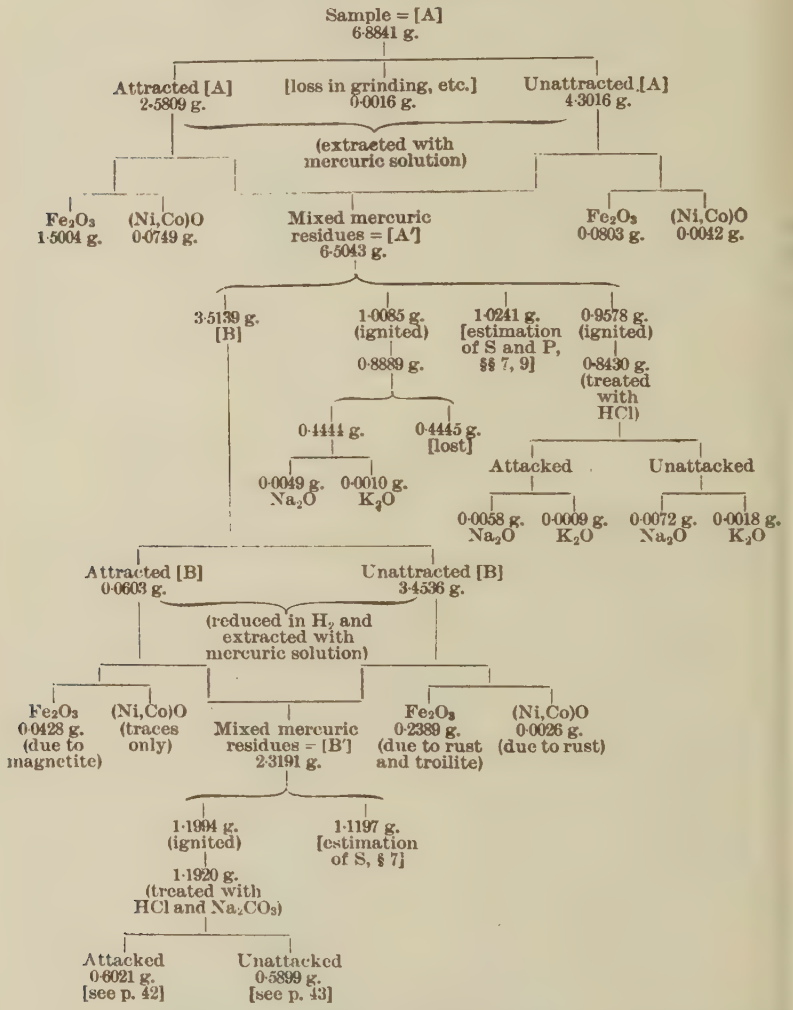
	Grams.	Grams.	Per cent.	Per cent.
Nickel-Iron Alloys:—Fe	1·2008	... ...	17·45	
Ni	0·0704	1·2837	1·03	18·66
Co	0·0125	... ...	0·18	
Magnetite		0·0763	...	1·11
Troilite		0·2821	...	4·10
Schreibersite		0·0117	...	0·17
Chromite		0·0034	...	0·05
Silicates:—				
Attacked		2·5955	...	37·71
Unattacked		2·6106	...	37·93
		6·8633		99·73

[Weight taken, 6·8825 grams.]

[1] E. Cohen, 'Meteoritenkunde,' 1894, Part I, p. 266.
[2] E. Cohen, ibid., p. 282.

§ 19. The somewhat complicated series of operations involved in the analysis are here set out in tabular form, for convenience of reference.

THE DOKÁCHI METEORITE.



The completion of the present work was delayed by the removal of one of us from Oxford, and our sincere thanks are due to Professor P. Phillips Bedson, M.A., D.Sc., who very kindly placed at our disposal his private laboratory at the Armstrong College, Newcastle-on-Tyne, where a portion of the chemical analysis was carried out.

COMMUNICATIONS FROM THE OXFORD MINERALOGICAL LABORATORY. No. XIX.

On the occurrence of Bertrandite at the Cheesewring Quarry, near Liskeard, Cornwall.

By H. L. BOWMAN, M.A., D.Sc.

Professor of Mineralogy in the University of Oxford.

[Read November 15, 1904.]

IN the year 1904, two specimens were sent to me by Mr. F. H. Butler for determination, which showed small, colourless, rhombic or oblong tabular crystals on granite. The crystals proved on examination to be the beryllium silicate bertrandite, which forms a new addition to the list of British mineral species.

This mineral was first described by E. Bertrand in 1880 from the quarry of Petit Port, near Nantes, and it has since been found at other places in the same neighbourhood as well as in the old tin-workings at La Villeder in Morbihan, and near Alençon and Limoges, though always in very small quantity. Outside France it has been found only in the neighbourhood of Pisek in Bohemia; and, in the United States, at Stoneham and elsewhere in Maine, Amelia Court House in Virginia, and on Mt. Antero in Colorado. At all these localities it occurs in a pegmatite or granite, and at many of them it is associated with beryl, through the decomposition of which it appears to have been commonly formed.

The specimens sent to me by Mr. Butler had been found by him in 1904 in the Cheesewring Quarry, situated in the parish of Linkinhorne; and since that time a number of other specimens have been obtained from this place by him and by Mr. Arthur Russell. The latter has also discovered the mineral at some other localities in Cornwall, while minute crystals of another beryllium mineral, phenacite, have been found by him at the Cheesewring Quarry and elsewhere.[1]

The following notes are the result of an examination of the original specimens, which Mr. Butler has kindly presented to the University

[1] See a paper by Mr. Russell, in this vol., p. 55.

Museum, and of a fine series collected by Mr. Russell, which he has kindly put at my disposal for the purpose. For the facts concerning the mode of occurrence I am further indebted to Mr. Russell.

The crystals of bertrandite are all tabular parallel to the face[1] c (001), and are usually rhombic in outline, though six-sided or oblong plates are occasionally observed. They are commonly 2 to 3 mm. in length by about 0·3 mm. thick; but crystals have been found as large as 11 mm. in length by 0·8 mm. thick.

The large faces have a pearly lustre, due to the perfect cleavage parallel to them, and show three sets of cleavage cracks corresponding, respectively, to a perfect cleavage along the short diagonal of the rhombs, b {010}, and to two good cleavages along the prism faces, m {110}.

Bertrandite from Cheesewring Quarry, Cornwall.

The crystals of rhombic and six-sided outline are bounded principally by faces of m {110} and b {010}, of varying relative size, and they frequently show small faces of f {130}, and sometimes also of a {100}. On one crystal a small uneven face of η {021} was observed. The faces around the edges of the plates (m and b) are vertically striated, and the large basal planes often show a division into two parts along the longer diagonal, with transverse striation or channelling on either side. Several crystals are often found growing together in nearly parallel position to form sheafy aggregates, in which the shorter diagonals of the plates lie parallel to one another. The oblong crystals, which are seldom met with, are bounded chiefly by a and b, with smaller faces of m and f.

Viewed under the microscope through the tabular face, the crystals show strong birefringence, with extinction along their diagonals; and in convergent light thin plates show the central portion of a wide-angled axial figure of positive sign, of which the axial plane is parallel to b (010) and the bisectrix in the centre of the field. The optic axial angle in olive-oil ($\mu = 1{\cdot}47$), measured in a thin cleavage-plate, was found to be $2H_o = 122° 30'$ for sodium-light. The refractive indices as determined by Dr. Herbert Smith's refractometer with a cleavage flake parallel to c (001),

[1] Letters and indices of faces as in Dana's 'System of Mineralogy', 6th edit., 1892.

are for sodium-light, α 1·584, β 1·603, γ 1·611; while the true optic axial angle, calculated from the formula $\sin V_o = \frac{\mu}{\beta} \sin H_o$ is $2V = 73°$. A cleavage-fragment bounded by faces of *c* and *b* was examined with a view to detecting any deviation from orthorhombic symmetry, such as was suspected by Scharizer in the bertrandite from Pisek;[1] but the obliquity of extinction, if any, did not exceed 20′, on either face, an amount too small (considering the imperfection of the material) to lend any support to Scharizer's view. Moreover, no change in the directions of extinction was observable on heating.

The crystals are strongly pyroelectric, as shown by Kundt's method; and, when hot, they adhere to the fingers.

The density of two crystals was determined by flotation in methylene iodide and toluene, and a Westphal's balance, and found to be 2·604.

The bertrandite occurs mostly on the sides of nearly vertical joints which traverse the granite in an east-and-west direction, and is usually associated with small crystals of quartz, and with white, blue, or violet fluor, and it is frequently penetrated by small needles of greenish tourmaline. The crystals are often stained brown by iron oxide, but become colourless on boiling with hydrochloric acid. The joints are sometimes three to four inches wide, and filled with clay, and their walls are lined with crystals of orthoclase, resembling adularia in habit, fluor, and quartz. Lower down they also carry wolframite and a small amount of iron-pyrites, and some specimens show traces of torbernite, and rarely small crystals of anatase and of reddish blende. One or two large polysynthetic crystals (up to three and a half inches across) of violet fluor, of octahedral habit and showing faces of cube, octahedron, and *v* {731}, and bearing clusters of bertrandite crystals on their surface, have been found in the joints. There is a second series of joints, running north and south, but these have not yielded any bertrandite.

A somewhat different mode of occurrence has been once noted in another part of the Cheesewring Quarry, where bertrandite has been found in a vugh with orthoclase (of the adularia-habit and sometimes showing Baveno-twinning) and purple fluor.

Of the minerals mentioned above as associated with the bertrandite in the joints, the anatase occurs in small black or tarnished bipyramidal crystals (*p* {111}, with small *c* {001}): the torbernite sometimes forms

[1] R. Scharizer, Zeits. Kryst. Min., 1888, vol. xiv, pp. 35, 40.

small dark-green crystals of two habits, viz. square tables with bevelled edges, and bipyramidal crystals without basal plane (closely resembling the two well-known habits of anatase).

Crystallized autunite has also been found, with fluor, in a joint in another part of the quarry, but it is not associated with bertrandite. Near this spot, in the centre of a patch of coarse-grained granite, transparent tabular crystals of pale blue apatite with pyramid-planes have been found, associated with quartz, Carlsbad-twins of orthoclase, and gilbertite—the specimens closely resembling those from the well-known apatite occurrence at Colcerrow Quarry, Luxulyan.

Bertrandite has also been found by Mr. Russell at the neighbouring Gold Diggings Quarry, as well as at East Kit Hill Mine, near Callington. All the other granite quarries in the district have, however, been searched by him for bertrandite without result.

It is worthy of note that in these localities the bertrandite does not appear to be associated with beryl, from which mineral it has usually been considered to be derived. Beryl is of extremely rare occurrence in Cornwall, and it has been recorded only from four localities in the west of the county.

Communications from the Oxford Mineralogical Laboratory. No. XX.

Note on the construction of models to illustrate theories of crystal structure.

(*With Plate III.*)

By H. L. Bowman, M.A., D.Sc.

Professor of Mineralogy in the University of Oxford.

[Read March 15, 1910.]

THERE are probably few subjects for the study of which models are more indispensable than the theories of crystal structure; but the provision of any considerable series of such models is costly, and they require, moreover, a large amount of space for storage. Some interchangeable models, which the author has lately had constructed to illustrate the space-lattices and the regular point-systems of Sohncke, and which may be fitted up and taken to pieces as required, have been found so convenient, both for lectures and for private study, that a short description of them may be found useful, although they differ only in details of construction from those suggested by Sohncke.[1]

In these models, the crystal-particles are represented by glass beads, fixed at equal distances on steel wires, which are supported, in the positions required, in a wooden frame covered with ordinary perforated zinc. The general construction of the models will be clear from an inspection of figs. 1 and 2 of Plate III, which represent, respectively, one of the space-lattices (the 'cube with centred faces') and No. 42 of the regular point-systems (the 'six-point-screw-system').

In the author's models, which are of a convenient size for a small class, the frames are 7 inches square and $1\frac{1}{4}$ inches deep, and are covered on both sides with squares of perforated zinc, having ten holes to the inch. Four long steel pins, projecting from the lower side of the frames,

[1] L. Sohncke, 'Entwickelung einer Theorie der Krystallstructur,' Leipzig, 1879, p. 179, and Pl. V.

fit into holes in the upright sides of the base, to keep the frame in position and serve as guides in removing or replacing it. These pins are visible in fig. 2, which shows the frame slightly raised off the base. The beads (of the variety known as 'curtain beads') are cemented on straight steel wires, chosen so as to fit nicely in the holes in the zinc, by means of a cement made of shellac with 10 per cent. of oil of cassia.[1] Very suitable wires, conveniently pointed at one end, may be made by cutting 18-inch knitting needles (which should be nickel-plated to prevent rusting) into halves. Each wire carries four beads, set 1·4 inches apart.

Care must be taken, in selecting the zinc, to see that the squares are free from irregularities in the perforation, so that the holes accurately coincide when two squares are superposed; and also, in fixing them on the frames, to see that the holes lie vertically over one another. The appearance and usefulness of the models depend very much on attention to this and to the accurate spacing of the beads.

The holes in ordinary perforated zinc are arranged in rows at 60°, so that the frames lend themselves particularly well to the construction of models with hexagonal or trigonal symmetry; but, since the spacing of the holes in two directions at right angles is as $1 : \sqrt{3}$, or nearly as $4 : 7$, it is possible to use them also for cubic and tetragonal models.

In the compound space-lattices and point-systems, which are composed of two or more interpenetrant simple lattices, the rows of beads forming certain of the constituent lattices are brought into the proper position by raising their wires by means of a suitable false bottom or 'inlay', which is placed on the base-board and kept in position by three brass pins, over which it fits.

Some forms of such 'inlays' are shown in figs. 1 to 5. That seen in fig. 2 is made by fitting short lengths, cut from a round wooden rod, into holes in a piece of $\frac{3}{8}$-inch board. For the 'centred cube' and the 'cube with centred faces', one, or two, of the simple cubic lattices are raised on strips of wood, arranged parallel to an edge (fig. 3), or to a diagonal (fig. 1), of the base of the cube, respectively. A convenient form of 'inlay' for the compound hexagonal columnar (No. 53, cf. fig. 11) and similar point-systems, consists of a sheet of thick millboard, in which are punched holes to allow the alternate wires to drop lower than the others by the thickness of the board. An 'inlay' made on the same principle may be used, as an alternative to the form seen in fig. 2, for the screw-systems. Fig. 5 shows such an 'inlay', made of zinc, for the compound rect-

[1] R. Threlfall, 'Laboratory Arts,' 1898, p. 88.

angular two-point-screw-system (No. 6), shown in plan in fig. 9. In this, holes are drilled in appropriate positions through one, two, or all three of the plates, to allow the wires to drop through. An inlay, consisting of a sloping plate of zinc, is required for the monoclinic and anorthic models.

When setting up a model, the wires carrying the beads are first arranged in the frame, as required; the proper 'inlay' is placed in position, and the frame and wires are then lowered on to the base, guided by the steel pins.

Two strips of the perforated zinc, cut from the sheet in the two rectangular directions, and having the holes numbered to serve as scales, will be found of great assistance in setting up. So also a templet, made of a square of cardboard punched with holes in the proper positions, would, if laid on the zinc, at once indicate the holes for the insertion of the wires, and save a considerable amount of time.

All the fourteen space-lattices may be readily represented by means of the models, as may also a considerable number of the sixty-five regular point-systems. The figures (figs. 6–11) show convenient arrangements of the wires in a few typical cases.

Special varieties of the general Sohncke systems, such as the 'bees' cell structure' (a special case of the compound hexagonal columnar system), can of course also be readily constructed. The tetragonal point-systems of Sohncke (general cases) cannot, however, be very well represented by means of the models (though an approximation to them is possible),[1] while the cubic point-systems require each a separate model.

[1] If it is desired to show the tetragonal systems, a frame may be fitted with a pair of zinc plates specially drilled with holes in the proper positions for the wires. One such pair of plates, drilled for the compound tetragonal columnar system (No. 36), is sufficient to enable any of the tetragonal point-systems to be constructed.

[*Explanation of Plate*, p. 54.]

Explanation of Plate III.

Fig. 1. Model of the 'cube with centred faces' (showing the form of the 'inlay', and the dense arrangement of the particles in the octahedral planes).

,, 2. Model of Sohncke's regular point-system, No. 42, the right-handed (one-threaded) six-point-screw-system. (The frame is slightly raised to show the guide-pins and the form of the 'inlay'.)

,, 3. 'Inlay' for model of the centred cubic space-lattice.

,, 4. ,, ,, rhombohedral space-lattice.

,, 5. ,, ,, compound rectangular two-point-screw-system (Sohncke, No. 6).

,, 6. Plan of wires for model of the anorthic space-lattice. The 'inlay' required is an inclined plate of zinc, sloping downwards towards the front of the model.

,, 7. Plan of wires for model of the tetragonal prismatic space-lattice.

,, 8. Plan of wires for models of the prismatic space-lattice of 120°, and the rhombohedral space-lattice.

,, 9. Plan of wires for models of the rectangular columnar system (Sohncke, No. 5, and Nos. 6–8).

,, 10. Plan of wires for models of the hexagonal columnar system (Sohncke, No. 47), and (with 'inlays') the one-, two-, and three-threaded six-point-screw-systems (Nos. 42–46).

,, 11. Plan of wires for models of the compound hexagonal columnar system (No. 53), and the corresponding screw-systems (No. 48-52).

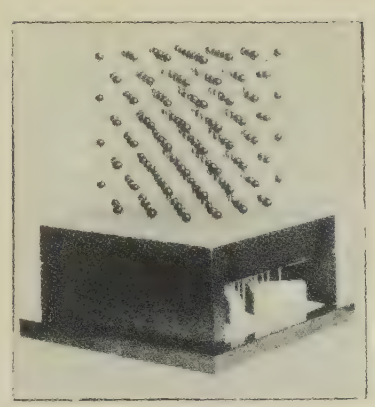


Fig. 1

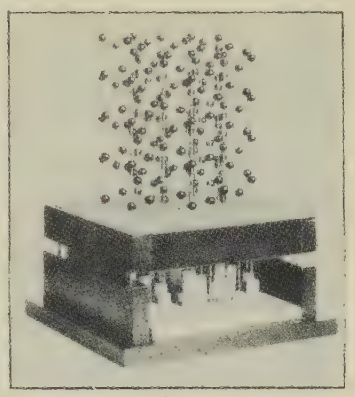


Fig. 2

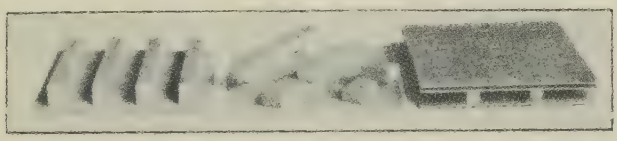


Fig. 3 Fig. 4 Fig. 5

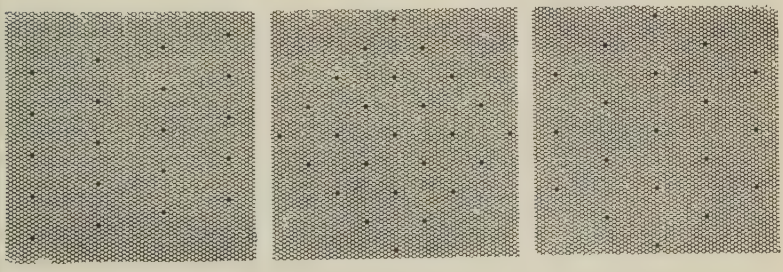


Fig. 6 Fig. 7 Fig. 8

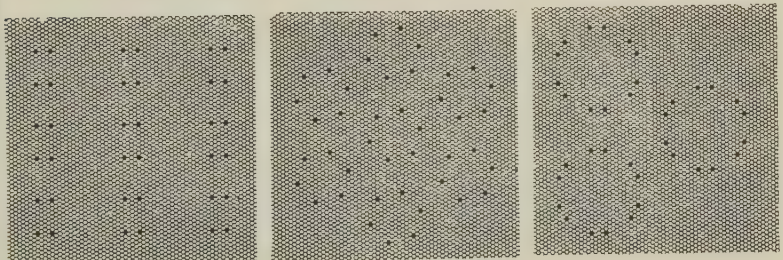


Fig. 9 Fig. 10 Fig. 11

H. L. BOWMAN: MODELS TO ILLUSTRATE THEORIES OF CRYSTAL STRUCTURE.

On the occurrence of Phenacite in Cornwall.

By Arthur Russell.

[Read June 7 and November 15, 1910.]

THE mineral phenacite (beryllium ortho-silicate) has not previously been recorded from the British Isles.[1] The following notes contain an account of its characters and mode of occurrence at five distinct localities in Cornwall. The occurrences are described in the order of their discovery.

Cheesewring Quarry, Linkinhorne, Cornwall.

During the early part of 1905, while examining the Cheesewring Quarry, in company with Mr. F. H. Butler, who on a previous visit had discovered bertrandite at this locality, I paid special attention to the discovery, if possible, of any other beryllium minerals. I was fortunate enough, after much searching, to find a specimen showing three small crystals that at once suggested the mineral phenacite; a surmise which on examination proved correct. The three crystals of phenacite, the largest of which measures $2\frac{1}{2}$ mm. in length by $1\frac{1}{2}$ mm. across, are colourless and of prismatic habit. They show the prism forms a $\{11\bar{2}0\}$ and m $\{10\bar{1}0\}$, which are deeply striated vertically, and are terminated by the rhombohedron of the first order r $\{10\bar{1}1\}$, the faces of which are large and somewhat rough. The crystals are optically positive. The specific gravity is 2·98.

The crystals lie horizontally on a dark green chloritic crust, and are closely associated with small doubly-terminated prisms of quartz, small octahedra of pale violet fluor, with here and there a thin plate of bertrandite, the whole occupying a joint-plane in a coarse-grained

[1] A crystal said to resemble Uralian phenacite, but possibly only beryl, was found by Dr. M. F. Heddle at Hillswickness Point, Shetland. It had rough faces, and was embedded in mica-slate (R. P. Greg and W. G. Lettsom, 'Manual of the Mineralogy of Great Britain and Ireland,' 1858, p. 473). This is not confirmed in Heddle's 'Mineralogy of Scotland', 1901.

muscovite-tourmaline-granite. The mineral appears to be very rare at this locality, for although I have since visited the quarry, which is extensively worked, and made careful search on no less than twenty occasions during the last five years, no more specimens have come to light.[1] The exact spot at which the specimen was found was in the quarry amongst the débris on the east side. The association of phenacite with bertrandite, octahedral fluor, and quartz in granite, recalls the occurrence at Mount Antero, Chaffee Co., Colorado,[2] although beryl, the common associate at Mount Antero, is totally absent from the Cheesewring Quarry.

South Phoenix Mine, Linkinhorne, Cornwall.

In 1906, more than a year after the discovery of phenacite at the Cheesewring Quarry, while examining some lode material which had recently been brought to the surface during the clearing out of an old shaft at South Phoenix Mine, Linkinhorne, Cornwall, I was rewarded by finding six specimens, all of which showed numerous phenacite crystals. These crystals are of long-prismatic habit, the largest being $4\frac{1}{2}$ mm. in length by $\frac{1}{2}$ mm. in diameter, and are plentifully scattered over the surface of the vein-stuff. They lie for the most part horizontally, and in some cases are attached to, or even penetrate small quartz crystals. The crystals are either perfectly colourless and transparent, or yellowish from a thin superficial film of iron oxide. Mr. L. J. Spencer, to whom I am particularly indebted for his ready help with regard to the crystallographic description of this and the other specimens here described, undertook the measurement of a crystal, with the result that the following forms[3] were identified: a $\{11\bar{2}0\}$, m $\{10\bar{1}0\}$, r $\{10\bar{1}1\}$, d $\{01\bar{1}2\}$, p $\{11\bar{2}3\}$, s_1 $\{3\bar{1}\bar{2}1\}$, x $\{12\bar{3}2\}$. Three faces of x and r are largely developed, those of the remaining rhombohedra being small (fig. 1).

[1] Mr. Hawkey the late manager, and Mr. Bennett the present manager of the quarry, have been most kind in affording me every facility in my search.

[2] S. L. Penfield and E. S. Sperry, Amer. Journ. Sci., 1888, ser. 3, vol. xxxvi, p. 321.

[3] Another crystal showed the same forms, but with only one face of r developed. On this distorted crystal the goniometric determinations varied somewhat from the calculated values for phenacite; for instance, the three angles xx' gave 76° 58′, 76° 58′, 76° 49′ (instead of 75° 57′). On all the other Cornish crystals of phenacite which were measured normal angles were obtained. The development of vicinal faces thus seems to accompany the distorted growth of the crystals, as previously observed on phenacite from German East Africa (Mineralogical Magazine, 1906, vol. xiv, p. 178).—L. J. S.

The vein-stuff on which the phenacite crystals occur is exceedingly typical of the Phoenix group of mines. It consists principally of greyish-white greasy-looking quartz, stained along its cracks with yellow films of limonite, and containing veins of blue 'peach', patches of black tourmaline, and also a little cassiterite, which latter is, however, invisible to the naked eye. The cracks or surfaces on which the phenacite crystals are developed are coated with small quartz crystals, the interstices being filled with earthy yellow limonite, and occasionally a little kaolin. The exact source of the mineral was a small heap of low-grade tin-stuff derived from Rodder's Shaft on an east and west tin-lode (South Prosper

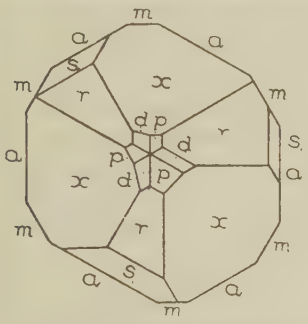


Fig. 1.—Phenacite from South Wheal Phoenix, Cornwall.

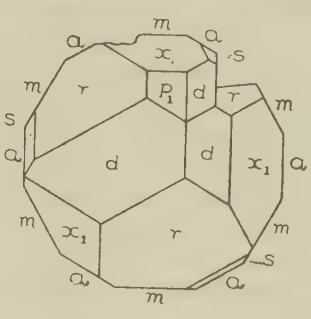


Fig. 2.—Phenacite from St. Agnes, Cornwall.

(Plans of crystals of long-prismatic habit.)

Lode) traversing the granite. The shaft is situated close to and just north of Cheesewring village, Sheet xxviii NW, Six Inch Ordnance Map.

Although the Cheesewring Quarry and South Phoenix Mine are only three-quarters of a mile apart, and both in the same granite mass, it is interesting to note that from the point of view of association the two occurrences are quite dissimilar. In the case of the Cheesewring Quarry the phenacite occurs in cracks in the granite in conjunction with quartz, fluor, and bertrandite; while at South Phoenix Mine it occurs in a tin-lode associated with quartz, tourmaline, and cassiterite. The fact that phenacite is observed to penetrate crystals of quartz proves it to be contemporaneous in formation with the latter mineral.

St. Agnes, Cornwall.

In 1909 the writer acquired an old collection of Cornish minerals, formerly the property of the late Mr. Alfred Fox, of Falmouth. In this collection was a very remarkable specimen labelled 'Topaz on Quartz

from St. Agnes'. A mere glance was sufficient to show that the crystals were not topaz, and examination proved them to be phenacite. The specimen measures 9 × 8½ cm., and consists of a clean group of opaque white quartz crystals, the largest of which is 6 cm. in length. Perched upon these, and even penetrating them, are no less than forty beautifully developed phenacite crystals of a pale wine-yellow colour. There is no rock attached to the specimen, and the only other minerals present are a few very small crystals of mispickel, and some small spheres of dark-green, scaly chlorite. The crystals are of long-prismatic habit, and are deeply striated vertically. They vary in size, the largest measuring 7 × 2 mm. Though externally of a pale wine-yellow colour, on rubbing between the fingers they become perfectly colourless and transparent, the colour being evidently due to an external film. The following forms were observed by Mr. Spencer, to whom I submitted a crystal which afforded excellent measurements: a {11$\bar{2}$0}, m {10$\bar{1}$0}, r {10$\bar{1}$1}, d {01$\bar{1}$2}, p_1 {2$\bar{1}\bar{1}$3}, s {21$\bar{3}$1}, x_1 {$\bar{1}$3$\bar{2}$2}. Three faces of each of the rhombohedra are developed with the exception of p_1, of which there is only one face present (fig. 2). In some cases two or more crystals have grown together, while some of the single crystals have deep channels running vertically down the prism-faces. The specific gravity is 2·98. Without a more precise locality than St. Agnes, it is unfortunately impossible to say from what kind of rock the specimen was obtained. Most of the St. Agnes mines are in killas, with the exception of a few in the western part of the parish, which are sunk in granite about St. Agnes Beacon. There is also a small outcrop of granite to the north-east at Cligga Head.

South Crofty Mine, Illogan, Cornwall.

Quite recently through the kindness of Mr. J. H. Collins I have been able to examine a remarkable specimen of a mineral which has proved to be phenacite. The specimen, though unrecognized, had been in Mr. Collins's possession for about forty years, and was found by him on a dump at South Crofty Mine, Illogan, Cornwall. The appearance and general character of the phenacite is very unlike that of the other specimens described in this paper, and, as far as I am aware, unlike the form in which the mineral presents itself at any foreign locality.

The specimen (No. 2123 in Mr. Collins's collection) measures 6 × 5 cm., and exhibits on one side a mass of long, white, radiating, prismatic crystals, some of which measure as much as 2½ cm. in length. One

prism more isolated than the rest has a diameter of 2 mm., and shows the forms m $\{10\bar{1}0\}$ and a $\{11\bar{2}0\}$, the prism-faces in this case being fairly smooth and bright, and the crystal quite colourless. A fragment showed the mineral to be optically positive, with fairly strong refraction, about 1·65, equal to monobromonaphthalene. Cleavage indistinct and imperfect; fracture conchoidal. Hardness about $7\frac{1}{2}$; scratches quartz with difficulty. The specific gravity is 2·98. Mr. W. F. P. McLintock, to whom Mr. Collins had previously submitted the specimen, has also identified it as phenacite, and informs me that he removed sufficient material to determine the presence of beryllium chemically.

The matrix consists almost entirely of dark green chlorite, containing numerous small bright crystals of mispickel and a good deal of disseminated brown cassiterite. A little quartz is present in immediate contact with the phenacite, and in one place there is a small patch of nearly colourless fluor. South Crofty Mine, which is still at work, is in killas, but strikes the granite at a depth of about 140 fathoms. In the year 1870, about the time that Mr. Collins found the specimen, the lower workings were well within the granite, which suggests that the phenacite occurred in a lode in that rock.

St. Day United Mines, Gwennap, Cornwall.

Quite recently yet another Cornish locality for phenacite has been discovered. A peculiar interest attaches to the find, inasmuch as the specimens, which are exceedingly fine, have, though unrecognized for about forty years, formed part of the national mineral collection in the Natural History Museum. The specimens, two in number, were originally labelled apatite from Redruth, Cornwall, and were purchased by the Museum authorities from Richard Talling, of Lostwithiel, the one in 1867, the other in 1872. Subsequently Mr. William Semmons pointed out that he had himself collected one of the specimens from a lode containing wolframite at the St. Day United Mines[1] about the year 1864, and that it had passed into Talling's hands. The specimens were described as apatite by Mr. Semmons in a paper entitled 'The Apatites of Cornwall in relation to their environments'.[2] Thinking the appearance of the crystals was very similar to those on the St. Agnes specimen of

[1] About the year 1856, Messrs. Pryor & Co., of Redruth, took over the old mines—Poldice, Wheal Unity, Wheal Gorland, and Wheal Maid, and consolidated them under the title of St. Day United Mines.

[2] W. Semmons, Journal Liverpool Geol. Assoc., 1892, vol. xii, p. 33.

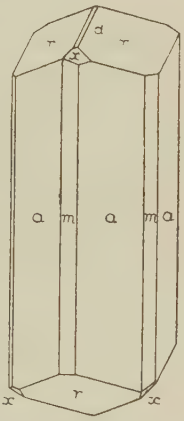
phenacite in my possession, I obtained Mr. Spencer's permission to examine the specimens more closely, when it was at once evident that they were phenacite, and not apatite.

The specimen (British Museum number 41069) purchased in 1867 consists of a mass of long quartz crystals cemented together, and coated over with globular, light-green, scaly chlorite; studded over the surface of which are numerous very beautiful crystals of phenacite. They are perfectly colourless and transparent, and of long-prismatic habit. A crystal detached from this specimen was measured by Mr. Spencer, and showed the forms $a\{11\bar{2}0\}$, $m\{10\bar{1}0\}$, $r\{10\bar{1}1\}$ large, $d\{01\bar{1}2\}$ small. The largest crystal measures $1\frac{1}{4}$ cm. in length by $1\frac{1}{2}$ mm. in diameter. A few of the phenacite crystals are seen to grow directly out of the uncoated quartz crystals. A little massive mispickel occurs on the back and sides of the specimen, and is the only other mineral present.

The specimen (British Museum number 44675) purchased in 1872 is an exceedingly beautiful one, and consists of a mass of very pale green to almost colourless fluor, one side of which is crystallized in cubes with well-developed dodecahedron faces $\{101\}$. Sprinkled over these cubes, and partially embedded in them, are numerous phenacite crystals, some perfectly colourless and transparent, others, the larger ones, slightly turbid in appearance. A crystal measured by Mr. Spencer showed the forms $a\{11\bar{2}0\}$, $m\{10\bar{1}0\}$, $r\{10\bar{1}1\}$ large, $x\{12\bar{3}2\}$ small. The largest crystal measures $1\frac{3}{4}$ cm. in length by $2\frac{1}{2}$ mm. in diameter, and has a polysynthetic development of the terminal rhombohedron faces. One transparent cube of fluor, about 1 cm. along the side, has included in it four beautiful little crystals of phenacite, and also a little chlorite. Besides the chlorite, quartz in broken prisms is the only other mineral present.

The finding of the above-mentioned specimens suggested that others of the so-called apatite from Cornwall might prove to be phenacite. I, therefore, examined the collection of British minerals (originally the Ludlam collection) in the Museum of Practical Geology, and was successful in finding, thanks to the kindness of Mr. W. F. P. McLintock, two further examples of the mineral. Of these, one bearing Talling's number 743 is from the St. Day United Mines, and is exactly similar to the specimen number 41069 in the Natural History Museum. The other was labelled 'Cassiterite, Apatite, and Quartz from Cornwall', but in reality consists of numerous deeply-striated prisms of phenacite embedded in black blende, which is both massive and crystallized, and in part coated with iridescent chalcopyrite. The rest, the bulk of the specimen,

consists of quartz. The prisms of phenacite are colourless to slightly brownish or turbid; the largest measures 10 × 2 mm.; they are mostly broken, and without terminations. In a cavity, however, there is one crystal that exhibits a fairly large rhombohedral face, probably $r\{10\bar{1}1\}$, also a very small crystal terminated by somewhat rough rhombohedral faces, the form of which could not be determined with any certainty. The general appearance and character of the associated black blende suggests Wheal Gorland as being the locality: this, however, is conjecture, and is mentioned merely for what it is worth.



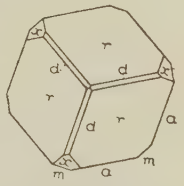


Fig. 3.—Phenacite from Wheal Gorland, Cornwall.

Wheal Gorland, Gwennap, Cornwall.

During August 1910 I visited the St. Day United Mines with a view to the possible re-discovery of phenacite, and after an extended search I was rewarded by finding a single well-defined specimen at Wheal Gorland. This mine, after a long period of abandonment, is at present being worked for wolframite by Messrs. Edgar Allen & Co., of Sheffield, the well-known firm of steel-makers. It comprises the northern part of Old Wheal Gorland, a mine famous in days gone by for the number of fine and rare minerals that it produced. The specimen of phenacite was lying amongst a small pile of rejected ore on the surface, but I am able to state, thanks to Captain James A. Temby, the manager of the mine, the exact spot underground whence this was obtained and its mode of occurrence, namely, a stope between the 10 and 20 fathom level, about eight fathoms east of the western shaft. The country-rock is granite close to its junction with killas, and the lode consists of wolframite, chalcopyrite, blende, quartz, fluor, and chlorite, also occasionally some native copper and cuprite. Captain Temby most kindly afforded me every opportunity for making a careful examination of the underground workings, but I was unsuccessful in finding any further specimens of the mineral. Unfortunately, from the collector's point of view, here as in most other mines nowadays the ore-bearing portions of the lode are trammed straight from the shaft's mouth to the crushers, while the waste material

is packed away in the worked-out stopes, and there is, therefore, little promising material in which to look for specimens.

The specimen to be described measures 12 × 9 cm., and consists of pale-green massive fluor, opaque white quartz crystals, chalcopyrite, black blende, and light-green earthy chlorite containing numerous small crystals of mispickel. The phenacite crystals, which are of long-prismatic habit, lie horizontally on, or are partially embedded in, quartz crystals; others, which are mostly much fractured, are embedded in blende or chalcopyrite. The crystals are mostly colourless, but some are slightly yellow. The largest measures 9 × 1¼ mm., and is doubly terminated; it has several transverse cracks and contains clouded areas due to internal flaws. The following forms, all of which are represented by smooth and bright faces, are present on a small crystal which was detached for examination: $a\ \{11\bar{2}0\}$, $m\ \{10\bar{1}0\}$, $r\ \{10\bar{1}1\}$ large, $d\ \{01\bar{1}2\}$ very small, $x\ \{12\bar{3}2\}$ medium (fig. 3). The prism-faces a and m are very deeply striated, giving the crystals a fluted appearance. The development of the terminal rhombohedron faces varies very considerably in the individual crystals; the r faces are, however, always prominent. Viewed from the top, certain of the crystals present a somewhat unsymmetrical appearance. On the crystal detached and examined only one face of x is developed, while d is represented by three very narrow faces. It is quite probable that the specimens previously described from the St. Day United Mines came from that part of Wheal Gorland now at work. Mr. Semmons's recollection of the occurrence, moreover, confirms this.

In conclusion, I would add that a careful search amongst old Cornish collections will probably result in the finding of more specimens of phenacite. The mineral, when in small crystals, such as those shown on most of the specimens described, is not easy to recognize at first sight, and it is probably for this reason that it has so long escaped notice as a British species.

The natural history of Kaolinite.

By Francis H. Butler, M.A., A.R.S.M., L.S.A. (Lond.)

[Read January 24, 1911.]

IN the south-west coal-field of east Glamorganshire—especially in the Lower Coal Measures—Mr. A. Tait, of Caerphilly, observed last year a white, soft, and pulverulent substance, saponaceous to the touch. A specimen sent to me, examined first and identified by Mr. T. Crook, was found to consist of a congeries of well-defined crystals of kaolinite. The crystals are chiefly basal flakes, hexagonal in outline, and 0·02 to 0·037 mm. in length. Most of them show elongation in one direction, and unequal extension of the thin lamellae composing them.

Mr. Crook has kindly provided me with the following details in proof of the identity of the mineral:—

'The specimen consists of a white, crystalline powder, and is seen, on examination with the microscope, to be made up almost entirely of small hexagonal plates and *rouleaux* of the same, which have the characteristic form and appearance of kaolinite. The maximum refractive index is less than 1·57, and the minimum greater than 1·56. Plates lying flat against the slide show a refractive index of very nearly 1·56 and exhibit little or no birefringence. In composition, the material is hydrated silicate of aluminium. A determination of water by loss on ignition, in a portion practically free from calcareous and carbonaceous matter, gave 13·78 per cent.'

The strata that carry the kaolinite are situated beneath some 200 feet of Pennant Grit. They comprise coal-seams, grits, fire-clays of varying degrees of purity, highly carbonaceous clayey shales, and hard shales locally called 'clifts'.

The changes that have taken place in the grits since their deposition have precluded the positive identification of kaolinite in microscopic sections prepared for the author. A grit taken from a depth of about 500 feet from the surface proved to be similar to the Pennant, except in presenting here and there minute pellets of altered dolerite, and in being rendered much darker in tint by diffused carbonaceous matter. Both rocks consist of angular quartz-grains set in a paste of decomposed

felspar, quartz, and abundant muscovite-mica. The mica is almost wholly such as results from the decomposition of felspars—a felt-work of ill-defined lenticular scales. These enwrap the quartz-grains, and are clearly of secondary origin. The remainder of the mica occurs in scattered fragments, whose regular outline and straight cleavage-traces imply derivation from a phyllite. In the interstices of the mica are little patches of granules that, owing to the close resemblance of cryptocrystalline quartz and kaolin, it is hazardous to pronounce upon definitely, although some exactly resemble the microscopic kaolin of various Cornish rocks.

The kaolinite may be traced, as specimens indicate, through every accessible bed of rock in the Measures: it may be seen lying along the cleavage-planes of the coal at a depth of 560 yards from the surface. The most abundant deposits, varying in thickness from that of a slight film to a quarter of an inch, form the central band in vertical fissures in the grits, which are lined with quartz and dolomite or calcite, and may be studded with pyrite and millerite crystals. Obviously the kaolinite was the last mineral to occupy the fissures. In places, more particularly along fault-planes, it is admixed with muddy and other foreign material. Its usual freedom from impurities and its loose state of aggregation probably point to quiet deposition from suspension in water that percolated through the Coal Measures.

The occurrence of kaolinite, either as a constituent or as a deposit, in Carboniferous and other sedimentary rocks has been repeatedly noted.[1] Its mode of origin in the Coal Measures is a problem to which it appears desirable to devote a few words.

R. Lang, in his account of the Middle Keuper Sandstones of Swabia,[2] effectually proves that their contained kaolinite is not a product of the weathering of felspar, the decomposition of the latter mineral having there been brought about by intra-telluric waters charged with carbonic acid. In the absence of proof that kaolinite once formed is capable of being dissolved by any acidulated or other waters known to exist in sedimentary rocks, it seems difficult to accept his view that the kaolinite of certain decalcified sandstones was deposited from solution in cavities vacated by calcite. One is tempted to surmise that the original felspar of the sandstones described was akin to bytownite or anorthite in composition, and suffered metamorphosis into calcite and kaolinite.

[1] See A. Lacroix, ‘ Minéralogie de la France,’ 1895, vol. i, pp. 467–470.

[2] R. Lang, Centralblatt Min. Geol., 1909, pp. 596–599.

As regards the Glamorganshire kaolinite, we may be certain that it is not a product of the weathering of the felspar-constituent of its parent rocks by surface-waters charged with sulphuric acid resulting from the oxidation of disseminated iron sulphide. The thickness of the cap of Pennant Grit, and its freedom from ferric iron, as intimated by its tint, also the abundant carbonaceous matter dispersed throughout the Measures, and the brightness of the pyrite wherever it occurs preclude the supposition that the oxygenation characteristic of weathering was operative during the chemical changes that produced the kaolinite.

We are restricted consequently to the conclusion that the kaolinization of the felspar of the rocks of the coal-field was the work of carbon dioxide in solution, that gas being a constant emanation from the coal-seams and carbonaceous shales, particularly those subjected to an elevated temperature at great depths. The existence of dolomite and calcite in the fissured grits is, in fact, sufficient evidence that the water in the Measures has been acidulated by carbon dioxide. That the kaolinite was of very slow growth is probably to be inferred from the geometric perfection of its crystals.

What we note in the Glamorganshire coal-field is essentially that which, according to C. Gagel,[1] H. Stremme,[2] E. Weiss,[3] F. Wüst,[4] and others, has been brought about in the upper regions of granitic masses by the carbonic acid of underground springs or of moor-water that has percolated through bogs, and has taken up in addition the humus-compounds crenic and apocrenic acids. Stremme remarks that weathering and kaolinization are produced only by weak acids at a somewhat low temperature, notably by solution of carbon dioxide, weathering being carried on with the co-operation of oxygen, and kaolinization in its absence, and presumably sometimes under the influence of reducing agents. That heated subterranean waters may contain carbonic acid he does not dispute, but he is of opinion that this would speedily be removed from action by combining with the salts dissolved thereby.[5]

Except as regards the source of carbonic acid, precisely similar chemical considerations seem to be necessitated in discussing the origin, on the

[1] C. Gagel, Centralblatt Min. Geol., 1909, pp. 437 and 467–475.

[2] H. Stremme, Zeits. prakt. Geol., 1908, vol. xvi, pp. 125–128.

[3] E. Weiss, ibid., 1910, vol. xviii, pp. 353–367.

[4] F. Wüst, ibid., 1907, vol. xv, p. 19.

[5] H. Rösler, Zeits. prakt. Geol., 1908, vol. xvi, p. 251, questioning the correctness of Stremme's description of a bed of altered rock as kaoliniferous, observes that it contains what appears to be a scaly sericitic mineral. That this has resulted from chemical change in kaolinite seems quite possible.

one hand, of the kaolinite and secondary muscovite and quartz of the kaolin-rock and greisens of Cornwall, and, on the other, of the kaolinite, mica, and quartz cement of the grits of the Welsh coal-field.

J. Morozewicz[1] has suggested that kaolinite, which has the composition $H_2Al_2Si_2O_8 . H_2O$, may, without its water of crystallization, be regarded as the first of a series of acids of which cimolite and pyrophyllite are respectively the second and third members. These have the general formula $H_2Al_2Si_nO_{2n+4}$, and yield the ions H_2 and $Al_2Si_nO_{2n+4}$. When n exceeds 4 the silicic acid is readily broken up. Orthoclase is the potassium salt of alumohexasilicic acid, $H_2Al_2Si_6O_{16}$, the fifth member of Morozewicz's series.

These premises furnish us with a clue to the transformations effected by carbonic acid in contact with orthoclase. We have first the conversion of the felspar into alumohexasilicic acid and potassium carbonate :—

Orthoclase.		Alumohexasilicic acid.	
$K_2Al_2Si_6O_{16}$	$+ H_2CO_3 =$	$H_2Al_2Si_6O_{16}$	$+ K_2CO_3.$

The acid, breaking up, yields kaolinite and silica :—

Alumohexasilicic acid.		Kaolinite (less water).	
$H_2Al_2Si_6O_{16}$	$=$	$H_2Al_2Si_2O_8$	$+ 4SiO_2.$

The potassium carbonate in the presence of the kaolinite, or alumodisilicic acid, produces muscovite, water, and carbon dioxide :—

Kaolinite (less water).			Muscovite.		
$3H_2Al_2Si_2O_8$	$+ K_2CO_3 =$	$2KH_2Al_3Si_3O_{12}$	$+ H_2O$	$+ CO_2.$

Carbon dioxide is thus seen to act merely as a carrier of the alkali metal : what is not removed by flow of aqueous solution or entangled in nascent silica is free to recommence the decomposition of orthoclase. Granted, therefore, a sufficiency of time, it appears unnecessary to postulate the presence of more than a comparatively small proportion of carbon dioxide for the conversion of vast quantities of felspar into an admixture of kaolin and muscovite.

For simplicity's sake no attempt has above been made to suggest the nature of the interaction of compounds of lithium and fluorine with kaolinite to form the micas of the china-clay districts of Devon and Cornwall.[2] Though boron must have been very generally present in the

[1] J. Morozewicz, Kosmos, Lemberg, 1907, vol. xxxii, p. 496 ; for abstract, see Zeits. Kryst. Min., 1910, vol. xlviii, p. 523.

[2] On the constitution of the micas, see F. W. Clarke, Bull. United States Geol. Survey, 1895, No. 125, p. 45.

magmas of the acidic igneous rocks of those counties, the possibility of fluorization quite apart from boration is distinctly there indicated by the existence of schorl-free greisen with topaz and schorl-free china-stone with fluor-spar and apatite.[1]

The earthy or poorly crystalline condition of the kaolinite of china-clay is presumably assignable to rapidity of production due to warmth. Lack of space for molecular movement during pseudomorphism not involving much loss of bulk and the presence of foreign matter (as exemplified in the distortion of ice-crystals formed on London pavements) may, however, have both adversely influenced the crystallization of kaolinite in china-clay.

If the genesis of kaolinite from felspar through the agency of carbonic acid may by now be regarded as proved by the results of a multitude of independent observations, including those of Bischof,[2] the upholders of Daubrée's hypothesis—that it is due to decomposition of felspar by boric and fluoric acids—are somewhat arbitrarily demanding the acceptance of two widely different explanations of one and the same chemical operation, i. e. the conversion of an anhydrous into a less-complex hydrous silicate.

A prolific source of error with respect to the nature and the period of the origin of kaolinite has been the frequent close association of kaolin with the products of tourmalinization—a process of repeated occurrence in the history of events in the geology of the west of England. There the existence of kaolin in commercially important quantities as a product of the alteration of granite is a purely local feature, referable to one period of pneumatolysis. Boration in addition to fluorization, however, can be shown to have taken place at various periods. Tourmaline, its commonest product, occurs in scattered crystals in granite both as an original constituent and as a substitute for primary biotite; also (in the radiating and acicular form) it replaces the micas and felspars of unkaolinized granites[3] and elvans, and the china-clay of kaolin-rock. This species of pneumatolysis, moreover, has not been confined to limited areas or to acidic igneous rocks only. The whole basis of the sedimentary strata of Cornwall and west Devon must in times gone by have been besieged by borated and fluorated liquids and vapours at no low tempera-

[1] For other examples of fluorization see F. H. Butler, Mineralogical Magazine. 1908, vol. xv, pp. 139-141.

[2] G. Bischof, 'Chemische Untersuchung der Mineralwasser zu Geilnau, &c.,' Bonn, 1826, pp. 302-309. See also J. S. Flett, Mem. Geol. Survey, 'Geol. of Bodmin and St. Austell,' 1909, p. 118, par. 2.

[3] J. J. H. Teall, 'British Petrography,' 1888, p. 314.

ture, and ready under pressure to sally forth along planes or channels of weak resistance. Thus, we find that tourmalinization did not take place merely along the contact-zones of sedimentary and igneous masses, and where kaolinization had facilitated the formation of fissures.[1] It played also an important part in the production of much lode-material in districts widely separated from the china-clay areas. It was, in addition, largely concerned in a far-reaching sporadic metamorphism of rocks, developing schorl in non-calcareous killas, axinite in calcareous killas, the Culm Measures, and doleritic intrusives, and datolite at the junction of serpentine with a hornblende-schist,[2] or deformed and metamorphosed enstatite-gabbro.

What has frequently proved a hindrance to the correct interpretation of episodes in the geological history of the west of England china-clay areas is the variety of appearances produced in constituents of rocks according to their distance from the main path of flow of a succession of pneumatolysing agents. Thus we find at Shilton, St. Austell, ordinary kaolinized granite passing almost abruptly into a rock with a groundmass composed of secondary white mica, schorl, and abundant highly vesicular quartz. The quartz is crowded with irregular liquid vesicles and negative crystals, each with a good-sized gas-bubble, and many a one with also a small cubic crystal. The larger china-clay pseudomorphs after orthoclase are replaced by a pearly white mica or by compact gilbertite. The gilbertite and white mica were clearly formed by a pneumatolysis, similar to that which occasioned the paragenesis of those minerals in the St. Stephens district. The gilbertite may be seen to have grown from within outwards, and to have been formed before the crystallization of the schorl, for the schorl skirts without penetrating it. The smaller china-clay pseudomorphs that, being near the ordinary kaolin-rock, have not been dissolved away or converted into constituents of the groundmass, show little change into gilbertite, possibly from the rapid leaching-out of basic constituents required for the formation of that mineral.[3]

[1] See Mem. Geol. Survey, 'Geology of Bodmin and St. Austell,' 1909, p. 108. The map of the St. Austell granite there given shows strikingly irregular extension of the kaolinized areas alongside the included tin-lodes—a feature favouring the view that kaolinization took place quite independently of and previous to the formation of the lode-fissures.

[2] W. F. P. McLintock, Mineralogical Magazine, 1910, vol. xv, pp. 407–408.

[3] The presence in china-clay of small quantities of bases not contained in kaolinite has been repeatedly demonstrated. Four samples of Cornish china-clay of the best quality analysed by W. Jackson and A. G. Richardson (Trans. English Ceramic Soc. Tunstall, Staff., 1905, vol. iii (1903–4), p. 56) gave an

Where pneumatolysis was most active in the Shilton rock and caused the rapid removal of kaolin, the place of mica is occupied mainly by quartz, gilbertite, and cassiterite; and the china-clay pseudomorphs after felspar are represented by cavities into which project needles of schorl, misshapen crystals of quartz, a little gilbertite, and abundant cassiterite. The deposition of the gilbertite in these cavities must have been coincident with that of cassiterite, for shapely crystals of it may be seen both alongside of and perched on the latter, as in some specimens of Zinnwald ore.

In St. Austell parish and elsewhere in the Hensbarrow district occur many other instances of the post-kaolinization boration of china-clay rock, proceeding along both sharply defined flat-walled fissures and irregular channels. The evidence of the kaolinized granites of the west of England is, in short, opposed to the opinion, adopted by some writers,[1] that their kaolinization was subsequent to the extensive tourmalinization to which wide tracts and broad courses and numerous veins of schorl and schorl-rock bear witness—an opinion obviously fostered by the persuasion that the china-clay of commerce must have been produced by the weathering of felspar.

G. S. O. Lasius[2] in 1789 first drew attention to the occurrence of schorl in the Harz Mountains at the contact of granite with other rocks; but it does not appear that he came upon any associated kaolin. He remarked that the schorl is a constituent also of mineral-veins in the vicinity of the granite, and that for this and other assigned reasons he was disposed to class it with lode-minerals. The significance of these observations appears to have escaped recognition by those who after his time attributed the kaolinization of granite to a pneumatolysis such as would produce tourmaline. Otherwise, taking cognizance of the fact that wherever metallic ores occur together with schorl in the china-clay districts of the west of England there is evidence of the work of pro-

average composition of alkalis 2·785, CaO 0·13, MgO 0·12, Fe_2O_3 0·625 with SiO_2 46·127, Al_2O_3 38·09, and water 12·157, in a total of 100·034. The proportions of the different mineral constituents were: clay-substance 97·372, quartz 0·89, felspar 1·685, in a total of 99·95. Still larger amounts of bases other than alumina were obtained in some of W. I. Macadam's analyses: see Mineralogical Magazine, 1886, vol. vii, p. 76.

[1] Cf. G. Hickling, Trans. Manchester Geol. and Mining Soc., 1908, vol. xxx, p. 355; and Mem. Geol. Survey, 'Geology of Land's End,' 1907, p. 58, par. 3.

[2] G. S. O. Lasius, 'Beobachtungen über das Harzgebirge,' 1789, Theil i, pp. 77–80.

cesses destructive of kaolin, they might have been led to question how the kaolinizing medium could have been that which generated the schorl.

To contend that because boron compounds, the results of a special kind of pneumatolytic action, occur in various rocks containing kaolinite, kaolinization is due to that action is an assumption that scarcely lends itself to the logic of facts.

Since the above was written the author has been favoured by Dr. J. S. Flett with a specimen of fine-grained Kinder Scout Grit (a division of the Millstone Grit) from Bamford Edge, north Derbyshire, thirteen miles south-west of Sheffield. From its altered felspar good kaolinite crystals can be teased out with a needle. In microscopic preparations the rock shows, interspersed among particles of quartz and a little unaltered albite, abundant fragments of orthoclase in various stages of decomposition into kaolinite. Crystals of kaolinite fleck the surface of the sections of felspar, or, less commonly, occur as an interstitial substance filling what seem to have been original cavities in the rock. Besides the kaolinite some of the felspars contain many small specks of mica, a few small clusters of which are also here and there perceptible in the cavities containing kaolinite. Between crossed nicols the higher polarization tints of the mica serve to distinguish it from the colourless kaolinite. This rock may be regarded as presenting the initial stages of the formation, by the agency of carbonic acid, of kaoliniferous grits such as those of the Glamorganshire coal-field.

REVIEWS.

Minéralogie de la France et de ses colonies. By A. Lacroix. Vol. IV, pp. iii.+923. (Paris: Ch. Béranger. 1910. Price 35 francs; of the four volumes, 125 francs.)

The first part of this valuable work appeared in 1893 and was reviewed in volume X of this Magazine; and the several parts—eight in all—have appeared at irregular intervals during the last seventeen years. A long break in their publication was occasioned by the author's important researches in vulcanicity, and his visits to Mt. Pelée in 1902–3, Vesuvius in 1906, and Etna in 1908. The gifted author is to be congratulated on the final completion of this magnificent piece of work, which easily ranks as the most complete treatise on the mineralogy of any one country that has yet been written. The four volumes contain a total of 3,295 pages, and are well illustrated by outline drawings of crystals and photographic reproductions of actual specimens. Much of the material is the result of the author's own extensive work, undertaken both in the laboratory and in the field; and, moreover, in discussing the relations between and the limitations of species there are many brilliant and original suggestions. Not only are full details given as to the crystalline form, optical characters, and chemical composition of the several species, but much is also said as to their mode of occurrence, associations, and origin.

The last volume treats of the Manganites and Plumbites; Sulphates and Chromates; Molybdates and Tungstates; Aluminates, Ferrites, and Chromites; Borates; Antimonites; Phosphates, Arseniates, Vanadates, and Antimoniates; Niobates and Tantalates; and Organic Compounds. Finally, there is a supplement of 238 pages which brings the preceding volumes up to date. Here we find a full account of the many remarkable minerals which within recent years have been discovered in Madagascar, and which have for the most part been worked out by the author himself. The only point calling for adverse comment is a large number of misprints.

Los Minerales de España. By Salvador Calderón. 2 vols., pp. viii + 416 + 561. (Madrid. 1910.)

This work has been issued under the auspices of the 'Council for the amplification of scientific studies and investigations'; and, as stated in the introduction, it is an amplification of the much smaller volume 'Die Mineralfundstätten der Iberischen Halbinsel' (Berlin, 1902), which was written conjointly by the late Professor C. A. Tenne, of Berlin, and the present author. It follows very closely on the same lines as this smaller work, but in rather greater detail and with the information brought up to date. Very little is given in the way of a general description of the mineral species; and after a brief introduction to each and a list of references to the literature, we pass to a description of the occurrences in the various provinces. To these are added a brief mention of occurrences in Portugal. There are 172 figures of crystals and specimens, which are mostly printed in the text, but some on separate plates.

Opuit opisatelnoĭ Mineralogiĭ. [*Essay of Descriptive Mineralogy.*] By V. I. Vernadsky. Vol. I, parts 1–3, pp. xi + 496. (St. Petersburg: Imperial Academy of Sciences. 1908–10. Price 5 roubles, 85 copecks.)

This is the commencement of what promises to be a very exhaustive treatise on descriptive mineralogy, but unfortunately being written in Russian it will not be generally accessible. The bibliography of 1,478 titles of books and papers, printed in their original languages and arranged under subjects, will, however, be found useful for reference; and especially so that portion (66 pages) relating to topographical mineralogy, in which the titles are arranged according to countries. There are, for instance, 44 titles relating to British minerals. In addition, numerous references to the literature appear in the footnotes in the descriptive portion of the work. The description of the native metals occupies 297 pages, and of the semi-metals 22 pages, while in the third part of the work the description of the non-metals (sulphur) is commenced. After the general description of each species, an account is given of its occurrence at various localities, more particularly those of the Russian Empire: for instance, 46 pages are devoted to the occurrence of gold in European and Asiatic Russia. Here we find mention of many Russian localities not given in the ordinary books of reference. The three parts of the work already issued are illustrated with 94 text-figures, giving drawings of crystals, pictures of specimens, maps, and local views.

The Mineralogy of Arizona. By F. N. Guild. Pp. 103. (Easton, Pa.: The Chemical Publishing Co. 1910.)

This small volume gives a brief account of the 120 species of minerals that have been recorded from Arizona. The information given respecting some well-known and important occurrences is somewhat meagre, and can only be regarded as a first sketch. Of special interest are the silicified wood and onyx-marble, the beautifully crystallized vanadinite and wulfenite, the secondary copper ores, the garnets and peridot of gem-quality found in ant-hills, the rare species spangolite and connellite, and the new species coronadite, morencite, and arizonite. We notice that Bettsomite is erroneously described as a silicate.

Die Anlauffarben, eine neue Methode zur Untersuchung opaker Erze und Erzgemenge. By Max Leo. Pp. 74, with coloured plate. (Dresden: Theodor Steinkopff. 1911. Price 2 Marks.)

Working on the lines indicated by J. Lemberg in 1894 and 1900 in his papers on the micro-chemical reactions of opaque minerals, the author has determined the action of various reagents in solution on metallic minerals. The reagents used include acids, potassium bromate, potassium cyanide, copper sulphate, &c., and the minerals so far examined are iron, copper, and nickel sulphides. By these means it is often possible to obtain a brilliantly coloured tarnish on a polished surface of the mineral. The surface so prepared is examined under the microscope in reflected light. Good tarnishes may also be obtained by an electrolytic method. The mineral specimen is wrapped round with platinum wire so that this is in contact at the sides but arches over the polished surface: this forms the cathode, while platinum foil forms the anode in a solution of copper sulphate or other metallic salt, through which an electric current of 3·5 to 5 volts is passed.

By such a method it is possible to distinguish one metallic mineral from another in a mixed ore; and it is claimed that pentlandite and chorbachite are mixtures rather than simple minerals. Faces of different crystal forms acquire differently coloured tarnishes; and when no faces are present, a crystal individual can be orientated by means of the tarnishes on various areas. Positive and negative crystals of iron-pyrites can also be distinguished. The method is the same as that known as heat-tinting, which has recently been developed by metallographers, though this is apparently unknown to the author.

Wachstum und Auflösung der Kristalle. By Arrien Johnsen. Pp. 27, with 10 text-figures. (Leipzig: Wilhelm Engelmann. 1910. Price 0·60 Mark.)

In this separately-published paper the author develops a theory of the growth and solution of crystals. Starting from the 'point of origin' in the crystal, which may or may not coincide with the point of symmetry and the centre of gravity, he distinguishes between 'real' and 'virtual' faces. The latter are small faces on the edges and corners of a crystal which are constantly changing their inclination to the real faces during the process of growth or of solution. The rate of growth or of solution in any one direction is given by the velocity with which a face moves parallel to itself. In the case of solution, the faces of the final form are those in which this velocity is a maximum, whilst in the case of growth the faces are those for which this velocity is a minimum.

Experiments were made on the growth and solution of cleavage cubes and spheres of rock-salt; these being immersed in large volumes of solution so that the concentration does not materially change. In a solution supersaturated to the extent of 2 per cent. the faces of the final form of growth are those of a very low tetrakishexahedron, whilst in one with a supersaturation of 4 per cent. the final form is the octahedron. The concentration of the solution thus has an influence on the habit of crystals. In a solution which is 2 per cent. under-saturated the final form of solution is also a vicinal tetrakishexahedron. The faces of growth and of solution are unstable and have in general complex indices, being vicinal faces. Only when the solution is exactly at the point of saturation do faces with rational indices occur.

Elementary Crystallography, being part one of General Mineralogy. By W. S. Bayley. Pp. xii + 241. (New York: McGraw-Hill Book Co. 1910. Price $2.00 or 8*s.* 6*d.*)

The material of this book was originally intended to form the introductory portion of an elementary textbook on Mineralogy, and in issuing it separately the hope is expressed that it may be of use to chemical and physical students of Crystallography. A second volume on minerals is to follow, so that the two together may be used by students of Mineralogy. The first part, headed 'Geometrical Crystallography', occupies the greater portion of the volume: this works through the several crystal systems and their hemihedral divisions. The Naumannian notation for crystal faces is used in preference to the Millerian, since it is

believed that the former is more readily grasped by elementary students. Part II (47 pp.) on Physical Crystallography includes short chapters on the mechanical, optical, thermal, electrical and magnetic properties of crystals, and on etched figures. Part III (7 pp.) gives a brief outline of Chemical Crystallography.

A special feature of the book is the very clear printing on good paper, and the clearness of the 311 text-figures. There are a few misprints, and the descriptions of the figures especially require revision.

Tables for Calculation of Rock-analyses. By ALFRED HARKER. Single sheet $17\frac{3}{4} \times 11\frac{1}{2}$ inches. (Cambridge: University Press. 1910. Price 1*s.*)

This is a compact and ingeniously arranged set of tables for calculating in a very simple manner the percentage mineralogical composition of a rock from the percentage chemical analysis. It is printed on thin cardboard, with the tables on one side and instructions how to use them on the other. A German translation has already appeared in the 'Centralblatt für Mineralogie, &c.' (1911, pp. 103–105, with folding table).

Mineralogisches Taschenbuch der Wiener Mineralogischen Gesellschaft, 1911. Pp. 192. (Wien. 1911. Price 10 Kr. = 8 Marks 50 Pfg.)

The flourishing Mineralogical Society of Vienna, founded in 1901, and now numbering 150 members, is a happy combination of the several scientific workers in the University and the Hofmuseum, and of interested amateurs and keen collectors. Its proceedings are published in 'Tschermak's Mineralogische und Petrographische Mitteilungen'. The pocket-book now issued by the society is edited by A. Ritter von Loehr, and contains contributions from Prof. F. Becke, Dr. R. Koechlin, Prof. C. Doelter, and O. Rotky. Rather more than half of the volume is occupied by a very complete alphabetical list of mineral names, about 6,000 in number, giving brief descriptions and synonymy, and a table giving the essential characters of about 1,000 well-established species of minerals. These have been compiled by Dr. R. Koechlin. Other items of useful information include: an account of the several public and private mineral collections in Vienna; history, statutes, and list of members of the society, and some particulars of the mineralogical societies of other countries; lists of mines in Austria of the various metallic ores and other minerals of economic importance; determination of gem-stones; radio-activity of minerals; address-lists of guides, collectors, and dealers. Excellent portraits are given of the two honorary members of the society, the

veteran Gustav von Tschermak, and Isidor Weinberger. The volume is issued in a small and handy form, and its only drawback appears to be its rather high price.

Introduction to the study of rocks, and guide to the rock collections in Kelvingrove Museum. By PETER MACNAIR. Pp. 79, with 6 plates and 52 text-figures. (Glasgow. 1911. Price 3*d.*)

This is a companion guide-book to that on the mineral collections which appeared last year (noticed in this Magazine, vol. XV, p. 333); both have been prepared by the curator of the natural history collections. In the collection, three cases are occupied by the rock-forming minerals; three cases by forty-five common types of igneous, sedimentary, and metamorphic rocks, illustrated by thin sections so placed that they can be examined with a lens, and by photomicrographs (scarcely microphotographs, as stated in the guide-book); and two cases by rock structures; while thirteen cases are occupied by the systematic collection of rocks, which are mostly from Scotch localities. The guide-book consists for the most part of a description and explanation of the contents of the first eight cases, thus forming a simple introduction to the study of the rocks. The book is a marvel of cheapness, and it should do much towards the encouragement of the study of geology in a geologically interesting district. It is well illustrated, but the drawings of crystals, though better than those in the mineral guide, still leave room for improvement.